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Barytes in Ireland

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DEPARTMENT OF AGRICULTURE AND TECHNICAL INSTRUCTION FOR IRELAND.

MEMOIRS OF THE GEOLOGICAL SURVEY OF IRELAND.

MINERAL RESOURCES.

BARYTES IN IRELAND.

BY

T. HALLISSY, B.A., M.R.I.A., F.G.S.

DUBLIN:
PUBLISHED BY THE STATIONERY OFFICE.

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EASON & SON, LTD., 40-41 LOWER SACKVILLE STREET, DUBLIN.

1923.

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ASSISTANT
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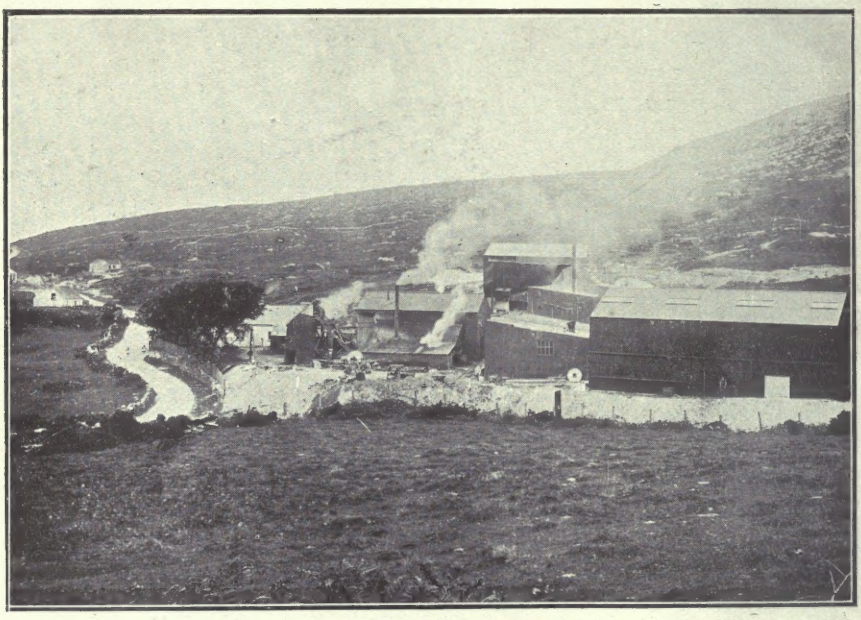
Duneen Bay Barytes Mines, Clonakilty, Co. Cork.



Frontispiece.] Dunmanus Bay Barytes Mines, Ballydehob, Co. Cork.

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PREFACE.

Some account of the mining of barytes in Ireland, with references to the principal localities, has been given in the Mineral Memoir issued by the Geological Survey of Ireland in 1922. Mr. T. Hallissy now brings together the results of his extensive observations in the field, and of a wide range of study in regard to the genesis of the lodes. For the first time a Cainozoic age is assigned, with much probability, to the Irish deposits, and it is suggested that the gangue at present associated with many of our sulphide ores is far younger in geological time than the deposition of the ores themselves. The relation of the formation of barium sulphate to the erosion-surface of the superincumbent rocks is here interestingly pointed out, and it is shown that the investigation of a mineral deposit may involve a question of geography. The earliest commercial use of barytes was probably in the manufacture of "white" pottery ware in Staffordshire, by Josiah Wedgwood, about 1770. Like the ores of cobalt and nickel, which were ascribed to the malevolence of goblins, or the potassium salts of Stassfurt, now so highly prized in agriculture, barytes was at one time thrown aside during the extraction of associated material. As Mr. Hallissy points out in Chapter VII., the utility of barytes widens as time goes on, and its mining has now become an important industry. It is hoped that the present Memoir may lead, not only to the further appreciation of existing mines, but to the prospecting and exploitation of undeveloped lodes in Ireland.

It is my pleasant duty to acknowledge the valuable assistance rendered by Captain Alan Smythe, Mr. Frank Ahier, Mr. W. W. Gore, Mr. Thomas Conacher, Mr. P. J. Daly, and several others connected with the Barytes Industry in Ireland, in the task of collecting the information brought together in this Memoir.

GRENVILLE A. J. COLE.

DUBLIN, *May*, 1923.

CONTENTS.

ILLUSTRATIONS.

FIGURES IN TEXT.

BARYTES IN IRELAND.

CHAPTER I.

INTRODUCTION.

Barytes was first raised for commercial purposes in this country in the early part of the nineteenth century (see p. 10), at a time when the industrial applications of the mineral were still very limited, and the number of barytes mines and workings elsewhere in existence small and unimportant. Ireland, accordingly, may fairly lay claim to be amongst the oldest of the barytes-producing countries of the world. (See Geol. Surv. memoir: "Localities of Minerals of Economic Importance and Metalliferous Mines in Ireland," 1922, p. 20).

Production began here, according to popular tradition, with the exploitation of the great barytes lode at Dereennalomane, near Ballydehob, in the county of Cork. In the initial stages of its development the workings were merely on the outcrop of the lode, and were naturally on a modest scale; but later they became very extensive when the mineral was extracted from depth by mining. Subsequently other barytes lodes were discovered in the district, and with the exploitation of these deposits the industry expanded to one of considerable importance.

But while active mining has been in progress in Ireland almost continuously since the inception of the industry, it cannot be maintained that the results, as reflected by the output, are all that could be desired, or that they bear a proper relation to the mass of material existing in the more important of the deposits. There are, perhaps, many reasons for this. But one of the chief causes which operated against the success of many Irish barytes mining companies was the lack of adequate financial backing, which is so necessary to the success of every mining enterprise. The history of barytes mining in Ireland is largely a dismal record of company failures, many of which are traceable solely to this cause. Want of sufficient capital necessitated the adoption of crude mining methods, and of primitive transport services for the conveyance of the mineral product from the mines to the nearest port. Under such conditions the output was naturally restricted, and the cost of production was so high as to leave but little profit to the proprietors. Whenever unforeseen mining troubles, depression of the barytes market, or other difficulties had to be encountered, there was no margin of safety left, and the mines had to close down. Rapid transfer of the mining

properties from one set of owners to another was, accordingly, the rule ; so that it is often a matter of no little difficulty for the inquirer to follow the fortunes of individual mines. Another fruitful cause of the restricted output of barytes in Ireland must be set down to lack of enterprize. Comparatively few of the Irish deposits have ever been adequately explored, and of these that have actually been proved to be economic, very few have been worked to their fullest capacity.

The earliest recorded Irish output dates back to the year 1854, when, according to the Mineral Statistics, 2,500 tons of barytes were raised at Derrenala (probably Dereennalomane) Mine, and 80 tons from other mines in Co. Cork. Up to the year 1871, however, the total recorded output did not exceed 10,000 tons, but apparently there were years of inactivity during which there was no Irish production. From 1872 onwards the official returns are complete, and are shown graphically in fig. 1. There was a prolonged period of depression from 1902 to 1909. Otherwise, up to the latter year, the figures indicate no very important variations. From 1910 to 1915 there was a sharp rise in the output, but the succeeding years again witnessed a steady decline.

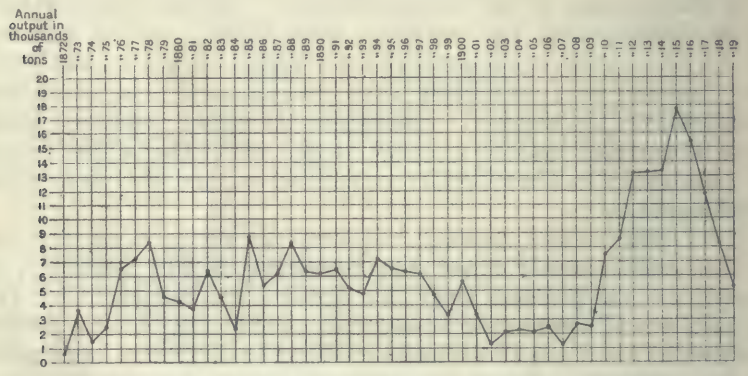


Fig. 1.—Annual output of Barytes in Ireland from 1872 to 1919.

Prior to the war, in spite of the many economic occurrences of barytes in the British Isles, more than 50 per cent. of the quantity required by British manufacturers had been imported, mainly from the Continent. Of these imports Germany supplied the great bulk. Favoured by the possession of large deposits of high grade barytes and by cheap transport rates, that country was enabled to compete successfully with the home producers. The paint trade, moreover, gave preference to the German product on account of the extreme fineness to which it was ground. This fineness, it may be noted, was achieved, not by any secret process, but merely by drastic grinding, the mineral having been passed through a battery of no less than 7-11 pairs of stones.

In 1913, the last normal year before the war, the output of the barytes mines of the United Kingdom was, according to the Home Office returns, 42,110 tons, having an average value at the mines of 12s. 1d. per ton. Of this quantity the Irish mines supplied 13,289 tons, or nearly one-third of the entire output. Its average value at the mines was 15s. 2d. per ton. When war broke out, the supplies from enemy sources were automatically cut off, and under the altered conditions, which threw the country upon its own resources, the home industry received a much-needed fillip. That the Irish mines responded somewhat to the stimulus may be gathered from the figures set out in the following table :—

Barytes Production in Ireland.

Year	Output in tons	Total value at the mines	Value per ton at the mines
		£	£ s. d.
1913 . . .	13,289	10,077	0 15 2
1914 . . .	13,384	15,304	1 2 10
1915 . . .	17,937	32,275	1 16 0
1916 . . .	15,329	40,553	2 12 10
1917 . . .	11,936	32,028	2 13 8
1918 . . .	8,123	35,725	4 7 11
1919 . . .	5,096	30,025	5 17 10

But, on the whole, the war did not materially affect the Irish production.

Very few companies were operating in Ireland during the period, and hence there was not the same room as in Great Britain for the expansion necessary to cope with the increased demand. To the companies actually engaged in mining, however, the enhanced prices then ruling brought considerable prosperity.

Expansion is possible in many directions. For example, under more favourable conditions, it might pay to re-open many of the derelict barytes mines of the Cork district that have been abandoned, apparently not through exhaustion of the mineral, but through water troubles, depression of the market, or other causes. Again, there are untapped barytes deposits of much promise, like those of Coolagh Beg and Cashelfean, that call for systematic exploration; while there is considerable room for increased production in the few mines that are at present being worked. Furthermore, in view of the increasing importance of lithopone for the paint and other industries, it might be possible in the future to

exploit the low-grade barytes of the metalliferous lodes to meet the requirements of this market.

All the barytes now produced in Ireland finds its way, either ground or in the crude lump, to the markets of Great Britain. That this has not always been the case would appear from the Report on Industries (Ireland) published as a Blue Book in 1885. From this report it may be gathered that, at least prior to that date, part of the barytes mined in the South of Ireland had been shipped to New York.*

Hitherto the production of barytes in Ireland has been confined mainly to the counties of Sligo and Cork, the bulk of the mineral having been raised from the lodes in the neighbourhood of Skull, Bantry, and Clonakilty, in the latter county.

CHAPTER II.

THE PROPERTIES OF BARYTES AND ITS MODE OF OCCURRENCE.

Although a full description of the mineral, barytes, may be found in any standard work on Mineralogy, yet it may be useful to discuss here some of its leading characters, with special reference to those of greatest diagnostic value.

Barytes, Barite, or Heavy Spar, as it is variously known in English-speaking countries, is composed of sulphate of barium, and is represented by the chemical formula $BaSO_4$; it contains in the pure condition 65·7 per cent. of barium oxide (BaO), and 34·3 per cent. of sulphuric anhydride (SO_3). It does not, however, always occur free from foreign matter ; very often it is found intermixed with small quantities of iron oxides, silica, carbonaceous matter, or other impurities ; while varieties containing strontium† and calcium sulphates are not uncommon.

Barytes crystallises in the rhombic system, commonly with a tabular prismatic habit. The richness of the development of crystal faces is very remarkable, no fewer than 119 different types of crystals having been described ; on this account the mineral is not always easy to recognise from its form alone. The cleavage, on the other hand, is a much more definite character, and hence of greater diagnostic value.

* Dr. W. K. Sullivan's Evidence, p. 19.

† In Ireland traces of strontium were found by Robert Mallet (Journ. Geol. Soc. Dublin, vol. x., 1864, p. 70) in barytes from the gangue of a lead lode at Dalkey, Co. Dublin ; while W. S. Barrett, in the course of the discussion on a paper read before the Manchester Geological Society (see Trans. of the Manchester Geol. Soc., vol. xxvi., 1900, p. 490), remarked that he had met with celestine ($SrSO_4$), or baryto-celestine in a mine in the South of Ireland. Mr. Dickenson, on the same occasion, stated that celestine had been found in several barytes mines in that district.

Barytes crystals possess three systems of cleavage. The most perfect of these is developed parallel to the basal plane, and perpendicular to this are two less perfect prismatic cleavages, parallel to the faces of the primitive rhombic prism. If a barytes crystal is subjected to shock or pressure, it is most liable to yield along the planes of cleavage. Hence, when fracturing takes place, the broken fragments mostly form rhomb-shaped plates bounded by these planes. Crystals belonging to the calcite group also break up in a similar manner, but with one important difference : the rhombs are never bounded by surfaces at right angles to one another. In the case of the barytes rhombs, on the other hand, the basal surfaces are always at right angles to the surfaces parallel to the prismatic cleavages of the crystal.

The usual lustre of the mineral is vitreous, but sometimes the cleavage-cracks within a crystal produce interference phenomena on the basal plane, and less often on the prism faces, giving rise to a peculiar pearly lustre which is quite characteristic. The mineral is often recognisable by this character in situations where it is not easy to apply the more usual tests.

Barytes crystals are found in nature grouped together in various ways. They may appear as coarse aggregates, sometimes as flat or curved plates in parallel series, or again, as dense granular or fibrous masses. The mineral is sometimes, though rarely, found in a massive granular condition, while stalactitic and concretionary forms have been described from a few localities. The crystals are commonly white, opaque to translucent, or even transparent occasionally. Frequently, however, the colour is affected by the presence of impurities. Thus the mineral is coloured a rusty brown by limonite ; reddish by impregnations of haematite ; and rose-red by manganese, even in small quantities. The dark-coloured variety, such as that of the great deposit of Meggen, Westphalia, owes its colour to the presence of bituminous matter.

Barytes is a heavy mineral, having a specific gravity ranging from 4·3 to 4·7. So that its great density may often serve to distinguish it, even in small fragments, from many other sparry minerals for which it might otherwise be easily mistaken.

The hardness of barytes, which varies from 3·0 to 3·5, serves to distinguish it especially from quartz (H = 7), with which it is so often intimately associated in lode-matter. The discrimination between them is conveniently made by means of a steel knife. This scratches barytes, but does not scratch quartz. Witherite, and the minerals of the calcite group run to about the same hardness as barytes, but they can be easily distinguished from the latter by their behaviour on treatment with hydrochloric acid. On the application of this reagent the carbonate minerals effervesce, either in the cold or upon heating, while barytes is unaffected.

Another character of the mineral of some importance is its

high melting-point ; it fuses with difficulty before the blow pipe, emitting the yellowish-green flame characteristic of barium compounds. If it is thoroughly fused with sodium carbonate on charcoal, and the melt is then placed with a drop of water on a silver coin, the silver is stained black, indicating the presence of sulphur. The powder of barytes thrown through the colourless flame of a bunsen gas-burner produces the characteristic yellow-green tint due to barium. The flame test and the sulphur reaction combined afford a convenient means of identification.

Under ordinary circumstances sulphate of barium is a practically insoluble substance, one part of the salt dissolving in about 400,000 parts of water. Nevertheless it has been found in solution associated with other salts in certain thermal springs. Lattermann has shown that the presence in the solvent of chlorides, such as $MgCl_2$, NaCl, and KCl, materially increases the solubility of the salt and retards its precipitation. These facts will be found of considerable importance when we come to discuss the genesis of barytes deposits.

Barytes is found most commonly in veins and metalliferous lodes, yet it is by no means confined to this type of deposit. Not infrequently it occurs in beds more or less concordant with the enclosing rocks, and it is found disseminated as minute crystals, or amorphous material, in various rocks of different geological ages. As in parts of the Galway granite, it sometimes occurs also in druses, or takes the form of nodules, or irregular patches, distributed sporadically through rock-masses.* In Triassic sediments, notably in the Bunter marls and sandstones, barytes is of very common occurrence. H. H. Thomas† found it as a cementing material of the Upper Marls and Sandstones of the New Red Sandstone series of Devon and Somerset. And again Beyschlag got traces of barium, probably as sulphate, in the Bunter Sandstone of the Thuringian Forest ; while Gräff found small crystals of barytes in druses occurring in the same series at Baden. The mineral has been found also in limestone and other rocks referable to various other geological periods.

In most of the cases cited the barytes is clearly of secondary origin, and there is good reason to suppose that this is so in every case, no matter in what situation the mineral is found. Its formation, as will be shown later, is determined by the interaction of infiltrating solutions containing barium with soluble sulphates arising within the rocks themselves.

At this stage it is of interest to inquire what is the origin of the barium found in the circulating waters. One at least of the possible sources of the element is not far to seek. It is

* Geol. Sur. Mem. to Accompany Sheet 95, p. 10, and Mem. to Accompany Sheets 105 and 114, p. 8.

† "A Contribution to the Petrography of the New Red Sandstone in the West of England." Quart. Journ., vol. lxv. (1909), p. 209.

well known that barium occurs in appreciable quantities in some varieties of the common rock-forming minerals. Amongst these many orthoclases of gneissic and granitic rocks, the plagioclases of basalts, and certain micas, like phlogopite, contain small quantities of the element. Exceptionally the amount is quite considerable. To cite a few instances, Penfield and Sperry* found 3·95 per cent. of BaO in a barium-orthoclase (cassinite) from Blue Hill, Media, Delaware County, Penn.; and Clarke and Hillebrand† give the analysis of a mica (phlogopite) in wyomingite, from Fifteen Mile Spring, Wyoming, containing 1 per cent. of the ingredient. The rare barium-felspars, hyalophane and celsian, contain as much as 7·5–16·4 per cent., and 16·5–39·5 per cent. of BaO respectively. When such minerals break down on weathering, soluble barium salts are formed and these eventually find their way into the ground water, and are then circulated through the neighbouring rocks in the superficial zone of the earth's crust. Since, however, the barium they contain is relatively small in quantity, it is insufficient to supply the material demanded by great barytes deposits, which are often found in situations far removed from such sources of mineralisation. The barium-content of the rocks in the vicinity of most barytes lodes, indeed, bears no proper relation to that of the lodes themselves. Hence, in order to account satisfactorily for the great accumulation of barytes in these deposits, it is necessary to postulate the rise of magmatic barium solutions through the containing fissures. On this hypothesis the formation of barytes lodes will be discussed in a later chapter.

All the commercially important deposits of barytes may be regarded as conforming morphologically to one or other of three types, viz. :—

I. Vein deposits.
II. The so-called bedded deposits.
III. Irregular deposits.

In the first category are included those barytes deposits accumulated by the infilling of crustal cracks and fissures produced by earth-movements after the rocks involved had become consolidated. Most of the Irish occurrences of the mineral belong to this class. The Irish lodes, nevertheless, differ widely among themselves. Sometimes the barytes forms the mass of the deposit, as in most of the lodes of the Cork district, where it is found practically free from admixture with other minerals. More frequently it appears in the veins as the gangue or matrix of metallic ores; while occasionally it occurs in bunches sporadically distributed along the course of a metalliferous lode.

* American Journ. of Science, vol. xxxvi., (1888), p. 326.
† Bull. U.S. Geol. Sur., No. 148 (1897), p. 115.

It is a very common belief among miners that barytes bodies have the special peculiarity of assuming lenticular forms when they occupy fault-fissures ; so that, when followed laterally or to depth, they will be found to widen and pinch alternately. While this is to a large extent true, it is equally true of the infillings of fissure-lodes in general ; for, provided the rock-walls are not corroded in the process, the material deposited from the mineralising solutions, no matter what its nature, is forced to take the shapes of the rock-cavities already provided for its reception. And since these cavities are most likely to be lens-shaped, so also the ore-bodies they contain.

In order to realise the mode of production of such open spaces, a cursory consideration of the ordinary process of faulting is all that is demanded. A fracture, as a rule, is not confined to a true mathematical plane, but is forced to take a sinuous path as it encounters beds of varying degrees of resistance. While it may retain its general trend in passing through soft rocks, it will be deflected from its course on crossing a hard stratum. In the latter case it will tend to cut the rock at right angles to the bedding, in the attempt to travel along the path of least resistance. The net result is that the fracture will swing to one side or the other according to the nature of the rocks it traverses. Let us now suppose dislocation to take place with respect to the plane of fracture. In the case of an ordinary tensional fault the principal movement is usually the gravitational sinking of the rock-mass on one of the sides of the fault. But accompanying this there may also be a horizontal component of the movement in the direction of the fault plane, thereby causing a differential shifting of the earth-blocks, as viewed in the ground plan.

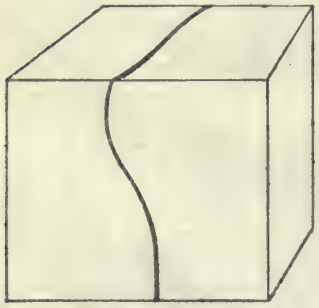


Fig. 2.

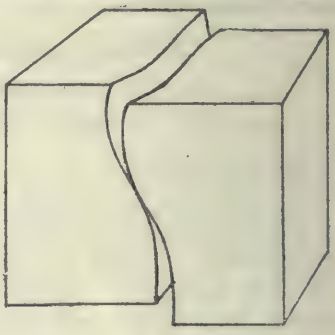


Fig. 3.

Figs. 2 and 3.—Diagrams illustrating the formation of lenticular spaces by faulting. (After Bärtling).

In any case, in consequence of the curvature of the surface of fracture, the walls of the dislocated rocks will no longer fit closely

together, and a series of open spaces will be left in every direction along the fault-plane. The production of these spaces is illustrated by the block-diagrams, figs. 2 and 3. The plane of fracture may take the sinuous form indicated by the heavy line in fig. 2. In fig. 3 the portion of the block to the right of the line is shown downthrown into such a position that the opposing walls will no longer come into complete contact, but will leave empty spaces that are lenticular in section. In nature the lenticular cavities are produced by a precisely similar mechanism, and as mineralising solutions find their way into them, vein-matter is deposited so as eventually to fill the whole of the spatial intervals between the rock-walls.

Although barytes-bodies do not differ morphologically from bodies of other vein-minerals, they are unlike the latter in the manner of their distribution through a fissure, taken as a whole. Metallic ores and other kinds of fissure-infillings have been known to persist for considerable distances along the course of a lode. Barytes, on the other hand, appears to be usually restricted in a fissure to within comparatively limited bounds, beyond which it gives place to quartz or to some other vein-matter. Its limited lateral range in a fissure would seem to indicate that the precipitation of the mineral was dependent upon the presence of some specific constituent of the enclosing rocks, and this inference is supported by the fact of the occurrence of barytes deposits localised in certain districts in the neighbourhood of definite geological horizons. The Skull and Ballydehob barytes deposits, to be described later, are cases in point. Here barytes is found in the fault-fissures where these intersect the copper-bearing grits towards the top of the Old Red Sandstone series, while it is absent from other parts of the same fissures, and from parallel lodes occupying fault-fissures of the same system cutting other horizons.

Another peculiarity of the distribution of barytes in fissures is the restriction of the mineral to the superficial portions of the lode. Barytes appears to be essentially a surface deposit, being practically confined to the zone of oxidation and the underlying part of the lode within the range of the oxidation products. When followed sufficiently far, it has always been found to fail in depth, giving place to quartz, fluorspar, or some other mineral.

Of the so-called bedded deposits of barytes, the only representative in Ireland is that replacing beds of dolomitic limestone, at Silvermines, Co. Tipperary. Although this deposit is not of very great economic importance, it is, nevertheless, of much scientific interest, as illustrating the metasomatic replacement of limestone by barytes.

Under the third heading are included barytes deposits, such as irregular bodies forming pockets in limestone, lumps in residual clays, etc., which cannot be classified either as veins

or beds. Occurrences of this kind, like the barytes lumps in the residual clays of Mineral Point, Washington County, N.Y., have been profitably exploited in other countries. No economic deposits referable to this class, however, have been found in Ireland.

CHAPTER III.

BARYTES DEPOSITS OF IRELAND.

Principal Occurrences.

Although there exist no written records bearing upon the origin of the Barytes Mining Industry in Ireland, it seems fairly certain that barytes was first raised in this country for commercial purposes in the district of West Cork. Local tradition has it that, nearly a century ago, the industry began with the extraction of the mineral from the lode till recently worked at Dereennalomane, 4 miles N.W. of Ballydehob. To Mr. James Bennett, a wealthy merchant and ship-owner of that town, the discovery of this deposit is popularly attributed. The circumstances which led to the discovery are obscure, but, according to the story related by one of the oldest inhabitants of the district, they arose indirectly out of Mr. Bennett's foreign trade connections. It appears that on one of this merchant's outward-bound vessels boulders of barytes were used as ballast, and that on the arrival of the vessel at its destination they attracted attention, which subsequently led to their identification and to the recognition of the economic value of the material. When Mr. Bennett heard of this, he proceeded to trace the boulders to their source, and his efforts were rewarded by the discovery of the great lode at Dereennalomane. Subsequently he worked the deposit at its outcrop, and shipped the barytes in the crude condition from Ballydehob, to what destination or for what industrial purpose could not be ascertained. It probably went to British potteries.

The existence of the barytes deposits of West Cork was first brought to the notice of the mining world by Thomas D. Triphook in a paper* read before the Geological Society of Dublin, in the year 1855. In this paper the author mentions some half a dozen occurrences of the mineral in the area, but unhappily his records of the localities are so indefinite that it is a matter of no little difficulty to identify the various deposits to which he refers. Of what he regarded as the principal lode, he is content to state that it "is situated between the Bays of Dunmanus and Roaring Water, County of Cork,

* "On the Occurrence of Sulphate of Barytes in the South West of the County of Cork." Journ. Geol. Soc. Dublin, vol. vi., p. 218.

and, as is usually the case of the mineral districts of this county, occurs on a hill side."

As, however, this lode was being actively exploited during Mr. Triphook's examination of the country, he took advantage of the opportunity to furnish us with a very full description of the workings, the mode of occurrence of the mineral, and its relations to the country rock. The internal evidence here available leaves little room for doubt as to the identity of the lode with that of Dereennalomane, to be presently described. The other barytes deposits mentioned in the paper are probably one of the Mount Gabriel lodes, and those of Derryfunshion, Derryginagh, Scart, and Duneen Bay.

Cork District.

Dereennalomane. 1″ Sheet 199 ; 6″ Sheet Cork 130 S.E.

In this townland a great lode of barytes, lying on the southern slope of Mount Corin, about a mile and a half due south of the head of Dunmanus Bay and about 4 miles N.W. of the town of Ballydehob, has been worked at intervals for nearly a century. It traverses the upper beds of the Old Red Sandstone, close to the junction of this series with the Carboniferous Slate. The rocks in the neighbourhood of the lode consist of grey and green slates and grits interbedded with slates of a purplish colour ; they strike from W. 25° S. to E. 25° N., dipping to the north at a high angle, while a cleavage, also steeply inclined towards the N., is developed parallel to the strike. Several of the beds in the immediate neighbourhood of the lode are copper-bearing, and on these a few old workings can be still seen from which a small amount of ore was extracted.

In its relation to the country rock the barytes deposit has all the characters of a true lode. It occupies a fault-fissure with well-defined walls, and since it bears N. 65° W., making the wide angle of 50° with the general strike, and dips about 80° to the S., it is independent of both the bedding and the cleavage. Evidence of the faulting is apparent from the condition of the walls as revealed in the underground workings. The hanging wall is much crushed and shattered along a zone varying in width up to a couple of feet, and the mixture of clay and slate into which the rock has broken down in this belt is suggestive of a considerable amount of movement. The foot-wall, on the other hand, is smooth and sound, but carries a small flucan lining, which serves the useful purpose of an indicator or leader for tracing the lode through dead ground. While its average bearing is as above stated, the lode does not run in a uniformly straight course, but undulates slightly about its general trend. Neither does the barytes fill the fissure in one continuous sheet, but alternately swells

and pinches both laterally and vertically, thus breaking up into lens-shaped bodies, separated by intervals of barren ground. In places also it cuts out suddenly as if the lode were broken by transverse faults. The lenses, however, are sometimes greatly elongated in the vertical direction. One of the richest shoots encountered in the workings, which at its widest point measured 20–23 feet across the breast, is said to have extended with variations in thickness from the surface to a depth of 500 feet.

Through the kindness of Mr. Frank Ahier, lately the manager of the Dunmanus Bay Barytes Co., it is possible to reproduce here a reduction of the Working Plan and Longitudinal Section of the mine (fig. 4), showing not only the mining operations carried out by his company, but also the extent of the former workings. In the Section the ground stoped by the Dunmanus Bay Barytes Co., is shown by cross hatching. The principal operations of this company were confined to one shoot, which has been successfully worked by them as far as the 86-fathom level. Here the walls came together, the mineral body having pinched out, but a bore-hole put down from the floor of the level to a further depth of 100 feet passed through another lens of barytes for a distance of 84 feet.

Other explorations in the neighbourhood of the shoot failed to tap any rich ground. At the 40–fathom level merely a small bunch of barytes was encountered in a drive of over 200 yards S.E. from the main shaft ; while only quartz, and small patches of barytes at 80 yards from the shaft, were passed through in another drift to the S.E., at the 53-fathom level. Additional explorations by borings from the surface were carried out in this section of the lode, but without success.

We have, unfortunately, no information as to the manner in which the shoots reached the surface above the level of the recent workings. Neither are there any details on the plan to show the distribution of the mineral in the western extension of the mine, the workings of which are now caved in. There is, however, good reason to suppose that it is this incaved western section that was being actively worked at the time when Triphook examined the mine, so that his observations may be fairly taken as applying to this part of the lode. In the paper referred to, he describes the deposit as widening in the horizontal plane from a mere thread up to a width of from 9 to 12 feet, and then contracting in a similar manner, maintaining an average thickness of 6 feet for a length of upwards of 6 fathoms. The surface-width of the lenses was found to persist in depth, or even gradually to increase downwards for a depth of 10 fathoms at the rate of 6 inches per fathom. In any case the shoots continued to descend without pinching, at least to the moderate depth to which the workings then extended.

In his paper Triphook implies, although he does not speci-

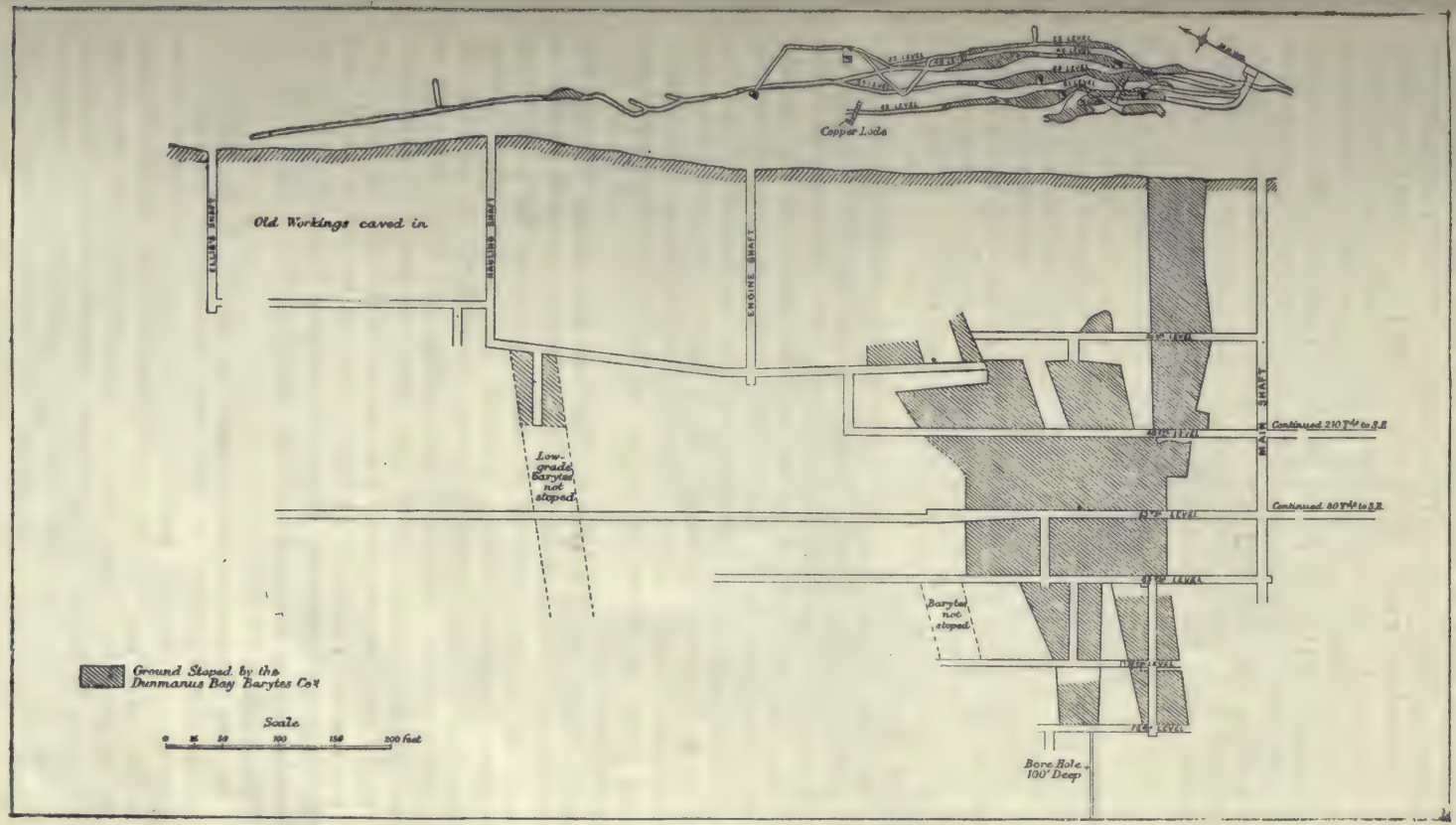


Fig. 4.—Working Plan and Longitudinal Section of Dereennalomane Barytes Mine.

fically state, that at the time of his visit the workings were reached by two shafts. It is now, of course, impossible to say for certain which these were, but the internal evidence would seem to point to their identity with those known as the Hauling Shaft, and Ellis's Shaft respectively. Thus, in a foot-note (p. 221) to his paper, Triphook remarks that, at a depth of 5 fathoms in the section of the mine then working, the lode gave off an east and west branch, which was followed for a short distance, and that a large bunch of barytes was raised at its junction with the main lode. A similar record appears in the old plan in the possession of the Dunmanus Bay Barytes Co. Near the surface, between the sites of these shafts, the lode is represented on this plan as forking, the main branch being 12 to 14 feet in width, and the smaller about 3 feet 6 inches. Since no other case of branching is known to occur in this deposit, it is highly probable that these two records refer to the same phenomenon. In the old plan the Hauling Shaft is represented as descending to a depth of 33 fathoms, and Ellis's Shaft, lying 220 feet to the W.N.W. of this, to a depth of 25 fathoms.

The bulk of the barytes from the Dereennalomane deposit is of the compact granular variety resembling marble in appearance, and is of excellent quality, being for the most part snow-white. In consequence of its compact structure, the mineral has proved singularly impervious to the penetration of iron solutions, and hence bleaching of the barytes with acid has never been found necessary. It is likewise comparatively free from quartz and calcium sulphate, but in places it is stained with green carbonate of copper in the neighbourhood of the cupriferous beds.

In recent years nearly all the mineral raised was ground on the spot before shipment. The treatment after extraction from the mine consisted of washing, drying in a revolving furnace, crushing, rolling between steel rollers, and milling. The last of these operations was performed by passing the rolled material through a steel mill, and then finishing off the grinding with one or two pairs of French buhr-stones. Finally the barytes flour was packed into bags, and conveyed by an aerial ropeway, $1\frac{1}{4}$ miles long, to an island jetty, near the head of Dunmanus Bay, and shipped thence to Liverpool, London, or Glasgow. The product was marketed as "Dunmanus White."

In the absence of more definite records it is difficult to follow the fortunes of the mine throughout its checkered history. As already mentioned, the deposit was first worked in the early part of the last century by Mr. James Bennett, of Ballydehob. Then, after an unrecorded period of activity, the mine is stated to have been abandoned for a number of years. We do not hear of it again until 1853, when Triphook visited the locality, and found that extensive mining opera-

tions were in progress, though he does not state under what auspices these were carried on. From 1862 to 1878 the mine is included in the Official List of Mines as worked by Martyn, Dennis & Co., under the title "Brandon Barytes." This is probably in error for "Bandon Barytes," since in the latter form it would at least be appropriately named after the Earl of Bandon, the landed proprietor of the ground, and the original lessor of the mining rights. There is a gap in the official records of the mine from 1878 to 1881, and presumably it was temporarily abandoned during this period. Mining appears to have been resumed under the auspices of the Durrus Barytes Co., in 1882, and active mining operations were carried on by this company up to the year 1890. Then Dereennalomane disappears again from the records for six years, and an indenture, dated November, 1896, would seem to indicate that during this period the mine remained derelict. In 1896, the property was leased by the Mount Gabriel Barytes and Umber Co., at that time the proprietors of the Mount Gabriel mines. This company achieved an output for three years (1897–99 inclusive), but then apparently got into financial difficulties, and closed down. After another period of inactivity the mine, in 1903, passed into the hands of the Irish Barytes and Umber Co., which seems to have been, about the year 1908, reconstructed as the Dereennalomane Barytes Mines, Ltd. The last-mentioned company went into liquidation in 1914, and disposed of its assets to the Dunmanus Bay Barytes Co., of 24 Finsbury Square, London. This company maintained a considerable output until early in 1920, when the mine was finally abandoned.

In the official returns the output has, in most cases, been incorporated with that of the other barytes mines of the Cork district. It has, however, been given separately in the following years :—

Year.	Output.	Year.	Output.
1883	150 tons.	1887	400 tons.
1884	1,000 ,,	1903	953 ,,
1885	800 ,,	1904	1,139 ,,

These figures are not very imposing, but the output of 6,339 tons for the year 1916, given in the report of the Department for the Development of Mineral Resources, is a better index of the productive capacity of the mine at its best.

Derryfunshion and **Caherolickane.** 1″ Sheet 199 ; 6″ Sheet Cork 139 N.E.

Another important barytes lode occurs at the boundary between the townlands of Derryfunshion and Caherolickane, about 2 miles W.S.W. of Dereennalomane ; it bears N. 30° W., crossing the strike and cleavage of the country rocks nearly

at right angles, and dips W.S.W. at about 70-75°. This would seem to be the barytes deposit mentioned by Triphook in the paper already quoted, where he speaks of a lode "running north and south," and "underlaying west" as situated about two miles west of the deposit now identified as that of Dereennalomane. On the assumption that Triphook recorded his bearings with reference to magnetic instead of to true north, the field observations as given above are in perfect harmony with his description of the deposit.

The rocks intersected by the lode are thick-bedded grey and green grits and slates, forming the copper-bearing horizon near the top of the Old Red Sandstone; and hence it occupies a position similar to that of most of the barytes lodes of the district.

According to information obtained from Mr. Con Moynihan, a local farmer, it appears that the deposit was worked about forty years ago on a rather extensive scale, operations having been carried on continuously for a period of ten or twelve years. The underground workings were reached by a shaft sunk on the lode to a depth of 40 fathoms, and through this the barytes was hauled by means of horse whims. An adit driven from a point about 100 yards to the east of the lode drained the upper part of the mine, and an engine which had been installed for haulage, but found inadequate for this purpose, was utilised to unwater the mine below the adit level. At the outcrop the lode is not more than 1 to 2 feet wide, but in depth it is said to swell out in places to as much as 10 or 12 feet in width. The barytes extracted was of a good white colour.

Transport difficulties appear to have seriously militated against the success of the mine. The mineral had to be carted to Dunbeacon, over a rough road, and for want of a suitable jetty at this port, it had to be taken thence in small boats, and transferred to larger vessels in deep water. The mining operations, too, were conducted in a rather primitive way, and the inability of the management to cope with the water troubles led finally to the abandonment of the mine.

Cashelfean. 1″ Sheet 199; 6″ Sheet Cork 139 N.E.

Near the summit of Knockaughna Hill a barytes lode cuts the copper horizon in the townland of Cashelfean, about $1\frac{1}{4}$ miles S.W. of the Derryfunshion-Caherolickane lode just described. The lode strikes about N. 50° W., apparently following a slack in this direction across the hill, and underlies to the S.W. The deposit is not well exposed, but where seen it runs to about 2 feet wide at the outcrop, and consists of good white coarsely crystalline barytes. Although in other respects very promising, it is not easy of access, being situated on a rough, steep hill-side, at a considerable distance from any good roadway. No workings or trials have ever been made on the deposit.

Mount Gabriel. 1″ Sheet 199; 6″ Sheet Cork 139 N.E.

Four barytes lodes appear on the northern and western slopes of Mount Gabriel, about 2½ miles almost due north of the town of Skull. These lodes, which are all parallel to one another, cut across the bedding and cleavage of the enclosing rocks, striking a few degrees south of east to north of west. They are grouped in pairs. The two northern lodes are separated by a horizontal interval of 220 feet, and some 400 yards away, the two southern ones are separated by an interval of about 300 feet. The grouping would suggest that the series originally consisted of two lodes, and that subsequently these were broken across and duplicated by a dip-fault which produced a differential shifting of the earth-blocks on the opposite sides of the fracture. No evidence of such a fault is to be seen on the ground, however, but a well-defined north and south fault-system is known in the district.

In this locality also the lodes cut a series of copper-bearing grits, some of which have actually been worked for copper. But while hitherto these beds have not been recognised as belonging to the well-known copper zone near the top of the Old Red Sandstone, the evidence based on the facts of the topography and the geological structure of the area is in favour of this interpretation, Since the thickness of the purple slates beneath the copper horizon does not here exceed 2,000 feet, and since Mount Gabriel is situated on the axis of a great syncline, and moreover rises to a height of 1,300 feet above sea-level, or about 1,000 feet above the general level of the surrounding country, there would appear to be ample room for the inclusion of strata as high in the series as those of the copper horizon.

For convenience of description the Mount Gabriel lodes will be numbered consecutively from south to north.

The first lode outcrops on the western shoulder of the mountain, and is traceable for about a third of a mile along its course. Standing nearly vertical, it underlies slightly to the north at the eastern extremity of its outcrop, but inclines to the south towards the western end. The barytes, which in places is intermixed with slate, varies in width from 1½ to 3 feet. The deposit was worked in a small way, through four adits driven on the lode, at different levels, from the side of the hill.

The second lode, which lies about a hundred yards to the north of the first, is seen outcropping for a distance of some 500 yards, and like the latter, it stands nearly vertical. At its eastern end the lode is two feet wide at its outcrop, swelling out in depth to 10 or 12 feet, but towards the west it narrows down to a mere thread. Beyond this the lode again widens, but the barytes gives place to quartz. The mining took place through two adit-levels, the higher of which tapped a very rich body of barytes, known as the "Big Breast." Over 3,000 tons of the mineral are said to have been extracted from this section of the mine alone. Dipping at 50° to the north, a small

subsidiary lode is exposed on the cliff escarpment above the principal workings, and this is said to join the main body of barytes in depth.

The third lode is situated on the northern slope of Mount Gabriel, about 400 yards N.E. of the last-mentioned deposit. Its outcrop is obscured by a covering of local drift, but it is traceable by the spoil-heaps appearing at intervals along its course. With regard to the actual workings there is no definite information available.

The fourth lode seems to have been the main source of the barytes raised in this locality. On the surface there are indications of rather extensive workings, especially near where the lode crosses the public road, a third of a mile N.W. of Barnacleeve Gap. These workings were reached by three shafts, the sites of which are shown on the 6″ Ordnance map.

Separate returns of the output from the Mount Gabriel Mines are given in the Mineral Statistics as follows :—

Year	Output	Year	Output
1894 . .	400 tons	1903 . .	200 tons
1896 . .	1,500 ,,	1904 . .	295 ,,

In the other years of their productive activity, the output is included with Dereennalomane and other mines. The deposits appear to have been worked in conjunction with the Letter lodes, first by the Mount Gabriel Barytes and Umber Co., and subsequently by the Irish Barytes and Umber Co. Since about the year 1907, the mines have been derelict. Recently, however, the Holywell Standard Chemicals, Ltd., have acquired the mineral rights of the townland of Mount Gabriel, with the intention of re-opening the mines to supply the raw material required at their chemical works. The barytes is an impure white, being much stained with iron.

Letter. 1″ Sheet 199 ; 6″ Sheet Cork 140 N.W.

In the townland of Letter, two-thirds of a mile to the west of Mount Gabriel, occur two parallel barytes lodes, bearing almost due east, and crossing the general strike of the country at a low angle. They are nearly vertical, and for upwards of a mile they are traceable as twin deposits, separated by only 210 feet of country rock. Like the Mount Gabriel lodes, they cut across the copper horizon of the Old Red Sandstone series.

On the 6″ Original Survey map the width of the southern lode is given as 2 feet, but this figure is probably intended to represent the average thickness, since in places it is said to widen to 4½ feet. The workings, which extended to a depth of 12 or 14 fathoms, were reached by three shafts The sites of two of these are represented on the 6″ Ordnance map.

Only one shaft was sunk on the northern lode, but some barytes was also raised from the open workings on this deposit.

towards the western end of its outcrop Here, the lode, as seen at the surface, consists of pure barytes, 2 feet in thickness, and of barytes and slate intermixed, 10 inches. The underground workings are said to have extended to a depth of 8 fathoms.

Both these deposits were exploited about the years 1889–93, by Messrs. Bordier and Cave, but the workings were on a comparatively small scale, only about 800 tons of the mineral having been extracted. The barytes is coarsely crystalline and generally white in colour. In places it contains specks of micaceous iron, more or less decomposed in the superficial parts of the lodes.

A small and apparently unsuccessful trial was made on another E.-W. barytes lode in this townland, 180 yards north of the principal deposits ; and on a parallel vein, still farther north, is seen the site of an old trial trench from which some good white barytes has been raised. This latter vein reappears on the side of the public road, a mile to the east, where it was worked to a small extent at its outcrop.

Skeagh. 1″ Sheet 199 ; 6″ Sheet Cork 139 N.E. and S.E. In the townland of Skeagh, on the southern slopes of Mount Gabriel, a barytes lode bearing N. 80–85° E., and dipping to the north at 75–80°, can be followed along its outcrop for upwards of half a mile. During the years 1917–19 the deposit was being explored by the Skeagh Barytes Co. (Captain Alan Smythe, and Messrs. Davis and Tierney, of Dublin), but subsequently, owing to the difficulty of procuring the necessary explosives, operations had to be temporarily suspended. The principal trials were made on the western part of the lode, in a favourable position, close to the horizon of the copper bearing beds of the Old Red Sandstone series (see Chapter V., p. 59). In this situation, too, the lode is decidedly promising, since at the surface, where it is exposed in the bed of a stream, it is seen to consist of pure white barytes, 1 foot 6 inches wide, and a mixture of barytes and quartz 4 feet 6 inches.

The explorations have been on a comparatively small scale. A short distance to the west of the stream exposure a pit was sunk on the deposit to a depth of 25 feet. The trial, however, proved unsuccessful, the barytes having cut out completely at this depth. In another effort to prove the deposit, an adit-level was driven on the lode from the side of the hill, 20 feet below the outcrop in the stream, and this was continued for a distance of 157 feet from the opening. From the floor of the level a winze was sunk to a depth of 32 feet, and at this depth short levels were driven east and west, as shown in the Longitudinal Section, fig. 5.

In these workings the greatest body of vein-matter was passed through in that part of the main-level almost vertically below the outcrop in the stream. Here the lode is 6 feet 6 inches wide from wall to wall, and on the foot-wall it carries a

rib of pure white compact barytes, 21 inches thick. The remainder of the infilling is made up of an intimate mixture of barytes and quartz, but in one place this is separated from the pure

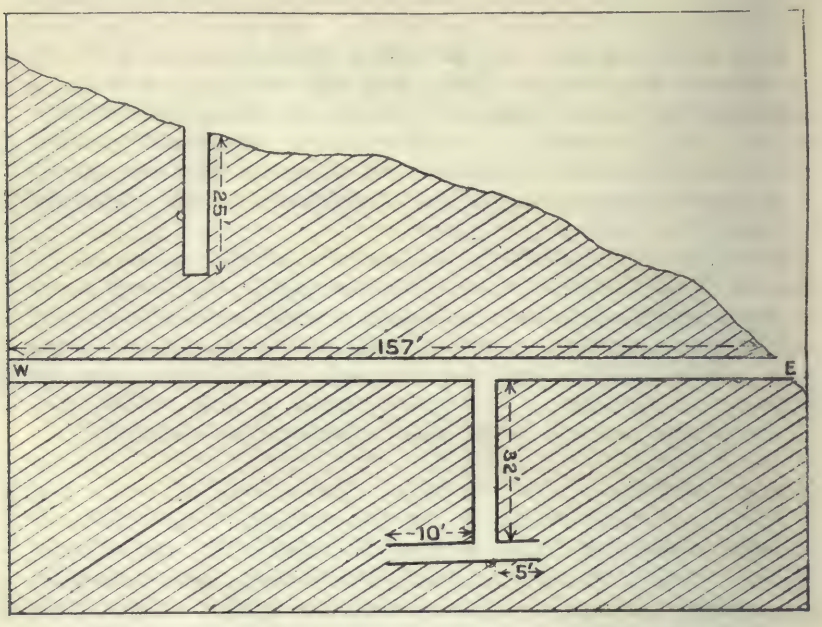


Fig. 5.—Longitudinal Section of Skeagh Barytes Mine.

barytes rib by a horse, i.e., by a portion of the country rock detached from the walls of the lode. The barytes diminishes in thickness towards the end of the level, giving place to quartz, 2 feet thick at the breast. During the trials some 150 tons of barytes of good quality were extracted and brought to grass ; this material is now lying near the mouth of the adit.

So far the trials have not been exhaustive, and until further explorations have been carried out, it is impossible to judge of the commercial possibilties of the deposit.

Glan. 1″ Sheet 199 ; 6″ Sheet Cork 139 S.E.

In this townland, about a mile and a half to the north-west of Skull, an east and west barytes lode traverses green and greyish slates and grits of the Old Red Sandstone series. These rocks are here and there impregnated with copper ore. At the outcrop the lode is 4 feet thick, and consists of quartz and barytes, much broken and intermixed with slates. The workings on the deposit were reached by an old shaft now filled with water.

In the same townland, two-thirds of a mile farther north, is another east and west barytes lode, occurring also in the Old

Red Sandstone. The workings on this deposit were rather more extensive. They were reached by an adit and two shafts. The shafts are situated 150 yards apart, and the adit follows the lode into the hill, 200 yards to the east of the eastern shaft. At one place, where a small trial was made on the outcrop, the lode is 2 feet thick, but here it consists only of quartz with specular iron. Near the shafts, however, the material seen in the spoils contains good white crystalline barytes, though sometimes stained with green carbonate of copper.

Some sixteen years ago both these deposits were worked by Mr. Arthur Cave, of Skull. After about 40 tons of barytes had been raised, the mines were abandoned.

Coolagh More and **Coolagh Beg.** 1″ Sheet 199; 6″ Sheet Cork 140 N.W.

Three barytes lodes outcrop in these townlands, about a mile N.W. of the town of Ballydehob. One of the deposits, which comes to the surface near the brink of a stream, at the eastern boundary of Coolagh More, consists, at the outcrop, of 4 feet of barytes intermixed with quartz and brecciated rock, and the lode is seen to widen as it descends. The barytes and quartz appear to be intimately intergrown, and associated with them are malachite and micaceous iron in small quantities.

A parallel lode, consisting of quartzose barytes, 1 foot 2 inches wide at the outcrop, lies about 60 yards to the north. Both the lodes bear due east.

The third barytes lode, which is very promising, occurs in the townland of Coolagh Beg. At its only exposure it is $2\frac{1}{2}$ feet wide, and consists of good white compact barytes of excellent quality. In consequence of the heavy cover of drift in the vicinity of the outcrop, the bearing of the lode and its relations to the country rock could not be determined.

No adequate trials have ever been made on any of these deposits.

The mining rights of the townlands are owned by Miss M. L. B. McCarthy, of Skibbereen, who is also the landed proprietor.

Ardrah and **Derreengreanagh.** 1″ Sheet 199; 6″ Sheet Cork 118 S.E.

A deposit of barytes, described by E. T. Hardman,* traverses the Old Red Sandstone series at the boundary between the townlands of Ardrah and Derreengreanagh, 1 mile S.E. of the town of Bantry. According to this authority, "instead of forming a lode it consists of a thick pipe-like mass of nearly pure barytes." In spite of his dogmatic statement, however, the alignment of the trials and shafts over a distance of 400

* "On the Barytes Mines near Bantry." Journ. R. Geol. Soc. Ireland, vol. v. (1880), p. 99.

yards would seem to indicate that the deposit must, after all, be regarded as a true fissure-lode, swelling out, indeed, at one point to a pipe-like shoot, and in places giving off subsidiary branches. On the 6″ Survey map the deposit is, in fact, recorded as a large vein, consisting of a width of 4 to 6 feet of barytes, with carbonate of copper and specks of copper pyrites; and it is represented as following the general strike of the country rock, which here is about N. 80° E. This representation of the bearing of the lode is, however, obviously incorrect, as may be gathered both from the surface indications, and from the course of the first level as given in the mining plan (see fig. 6). The deposit really cuts across the general strike at a fairly wide angle, running in the direction W. 15° N. to E. 15° S.

The pipe, according to Hardman, "is about thirty feet long and fifteen feet wide, and it has been proved to extend downwards, for at least ninety feet, having been excavated to that depth. At the corners it throws off small branches or veins, from two to five feet thick, and some of these have been found at the surface some distance from the main body, but appear to die away on every side.

"This great mass is almost entirely composed of the very purest sulphate of baryta. An analysis of it showed it to contain over ninety-five per cent. of the sulphate. The 'seconds' or 'cawk' (which forms but a very small proportion of the lode, being principally confined to the walls), contain various copper ores, the green carbonate, Peacock ore, and copper pyrites, as well as galena, all in very small quantity. The walls of the lode are coated in some places with steatite, or chlorite."

The mine, which has been known by the name of the Scart Barytes Mine, was first opened about the year 1876, by J. E. Dorrington, of Stroud, Gloucestershire, and actively worked under his auspices until 1881, when apparently it closed down. The output for this period, as given in the official returns, is as follows:—

Year	Output in tons
1876	201
1879	1,150
1880	130
1881	91

During the years 1890–93 the mine was again actively worked by J. T. Matthews, but on what scale the operations were conducted cannot be inferred, since the output for this period was not separately returned. It then remained derelict for some years, but was re-opened in 1908 by the Liverpool Barytes Co., Ltd. After another short period of activity, during which the deposit was thoroughly explored, and about 500 tons of barytes were extracted, the mine was finally abandoned.

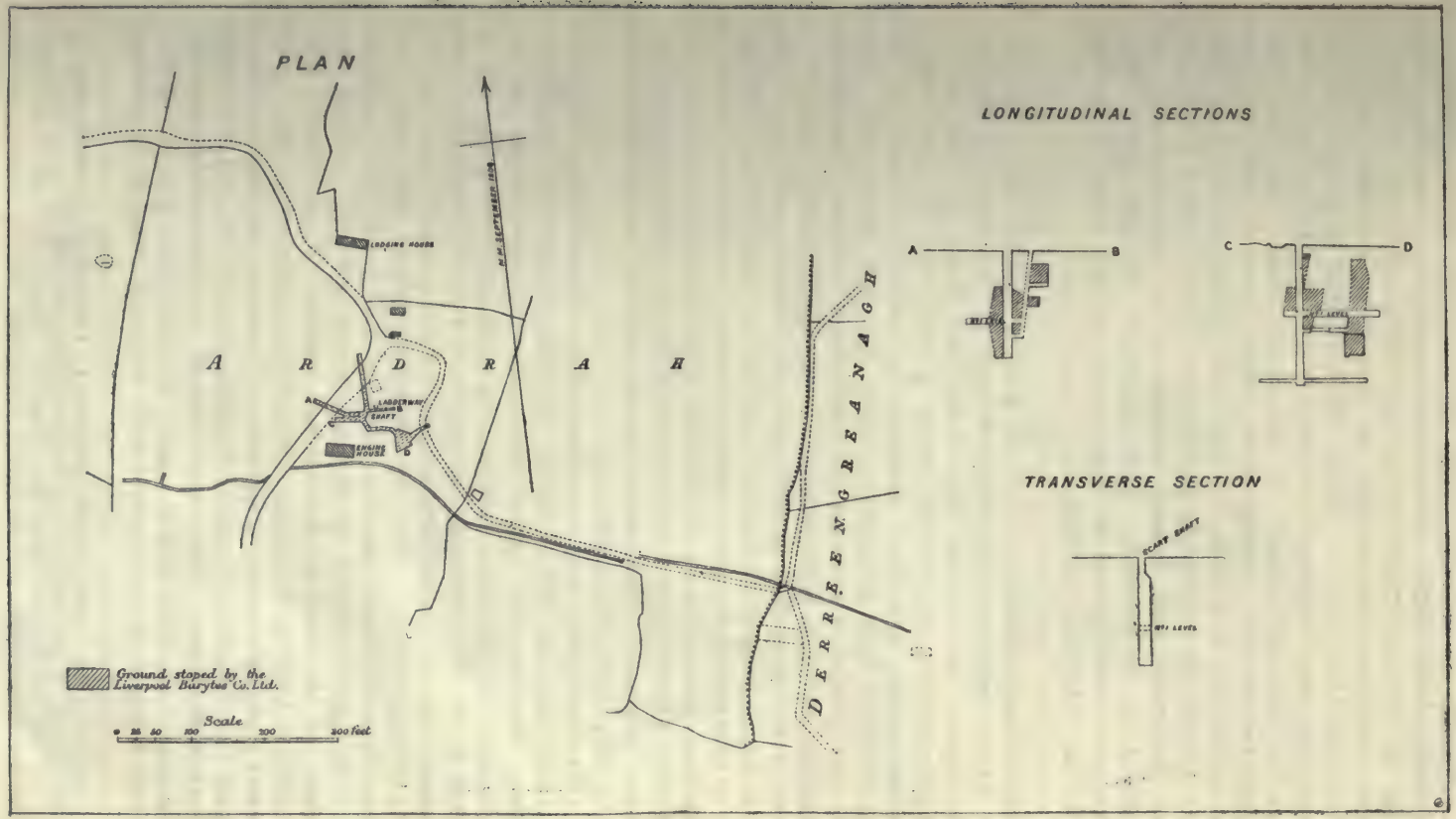


Fig. 6.—Plan, Longitudinal Sections, and Transverse Section of Scart Barytes Mine.

Through the courtesy of the officials of the Mining Statistics Branch of the Home Office, we are enabled to reproduce here (fig. 6) reductions of the plan, longitudinal sections, and transverse section of that part of the mine exploited by the Liverpool Barytes Co. From these it will be seen that the workings were reached by a ladderway, and by a shaft sunk on the lode to a depth of about 145 feet. The lode was stoped chiefly from the first level, which connects with the shaft at about 110 feet from the surface. Where widest, the principal body of barytes is said to have been from 8 to 10 feet at the breast, but it soon diminished in width laterally, and ceased to be payable. The mineral is of the pure white compact variety, and is stated to be nearly equal in quality to that of Dereennalomane.

Derryginagh Middle.* 1″ Sheet 192 ; 6″ Sheet Cork 118 N.E.

In this townland, 2 miles due east of the town of Bantry, a deposit of barytes traversing the slates of the Lower Carboniferous, near their junction with the Old Red Sandstone series, has been extensively worked at intervals for more than half a century. But although during this time it has yielded a considerable amount of mineral, the mining operations have been confined to a comparatively small area, not more than 200 or 300 yards in length, and the deposit has never been traced beneath the drift beyond these workings. For this reason it is impossible to arrive at a definite conclusion with regard to the exact relations of the deposit to the country rock. The occurrence, however, is in the nature of a fissure-lode, probably intersected at a low angle by a counter lode at the site of the workings.

Hardman, who had an opportunity of examining the mine, about the year 1877, when it was being worked by the Bantry Bay Barytes Co., gives the following description of the deposit† :—" It bears nearly due east and west, N. 80° E. and S. 80° W. ; cutting the strike of the Old Red Sandstone [really Lower Carboniferous] slates, at an angle of about ten to fifteen degrees. The lode is ten to fifteen feet thick, and has been followed for some 200 or 300 yards, the workings extending to a depth of about fourteen fathoms. About one-third of the lode in the centre consists of extremely pure barytes, but the sides of it consist of an impure variety called cawk, which contains a quantity of quartz, carbonate of lime, green carbonate of copper, Peacock copper ore, and micaceous or specular iron. The last is found in considerable quantity, so much so, that the manager of the works was of opinion that it might prove commercially valuable could it be smelted.

* Also given in the Mineral Statistics as Deriganagh, Derrygranagh, etc. (See Memoir of the Localities of Economic Minerals and Mines, p. 18.)

† " On the Barytes Mines near Bantry." Journ. R. Geol. Soc. Ireland, vol. v. (1880), p. 99.

"Besides the difference in purity of the barytes, two varieties occur in this lode. One a crystalline glassy-looking specimen; the other a granular saccharoidal variety, and the last is the kind most valued, as it is the most easily ground in the process of preparation.

"From this mine a considerable quantity of mineral has been obtained and exported by the Bantry Barytes Mining Company, who are now working it. When in full work they can easily turn out twenty tons a day. But the mine is capable of yielding a much larger quantity, being in fact so far only limited by the amount of labour obtainable, and the state of the market. Owing to the cost of carriage also, the price of the mineral is necessarily rather high."

Subsequent workings have demonstrated that the deposit is not so uniform in its dimensions as Hardman's description would imply. It has been found, in fact, to vary in width ordinarily from about 5 feet to 15 feet, swelling out to as much as 18 feet at the "Big Hole." The main lode dips to the south at about 80°, and is enclosed between hard walls, except in one place on the foot-wall, and in another on the hanging-wall, where 3 or 4 inches of clayey flucan intervene between the barytes and the solid rock.

The mineral has been extracted by means of both daylight and underground workings. The latter have been reached by four shafts sunk at different stages of the development of the mine. Of these the western shaft, situated in the neighbourhood of the "Big Hole"—an underground excavation, from which a large body of barytes has been extracted—descends about 176 feet from the surface. Lying 50 feet to the east of this is the New Shaft, 170 feet deep, which is the one now in commission; and beyond it is the site of an old shaft, long since fallen into disuse, which is said to have reached only to a depth of 75 feet. That at the eastern end of the mine is 300 feet deep, and was sunk in recent years by the Liverpool Barytes Company. The barytes was stoped from levels driven on the lode at vertical intervals of 10 fathoms that connected with these shafts.

A considerable bulk of barytes has been raised from a large opencast working situated immediately to the south of the old 75-foot shaft. Besides the main lode there are exposed in this opening a small vein of barytes crossing the main lode at a low angle, and either a branch of the main lode, or an independent parallel lode, consisting of good white barytes, 5 feet in thickness. This last deposit was accidentally discovered through the fall of a mass of rock on the southern wall of the excavation.

Not all the barytes obtained from this mine can be regarded as of the best quality. As Hardman implies in the above extract, only about a third of the lode-material can be classed as first grade. The marginal parts of the deposit are often

reddish or dark-coloured, and intermixed with quartz and specular iron. Both the compact and crystalline varieties of the mineral are represented. The barytes obtained from the "Big Hole" was compact and bluish in tint, and has been described as ringing like flint on being struck with a hammer.

According to the Survey Memoir,* the lode had been partly opened sometime before July, 1864, but mining operations were in abeyance at that date. From the returns in the Mineral Statistics it would appear that the mine was re-opened by the Bantry Bay Barytes Co., and worked by them from about 1877 to 1885. Subsequently, with short intervals of inactivity, the mining was continued by Alfred Foster (1888–1890), Peter Brown (1891–1896), and E. J. Whelan (1906–1908). About the year 1908 the mine was taken over by the Liverpool Barytes Co., and was worked in conjunction with the company's Scart and Duneen Bay barytes mines, until the year 1918. The property then passed into the hands of the Cookson Barytes Co., Ltd., Newcastle-on-Tyne, who are the present proprietors.

The output of the mine in the few years for which separate returns are available is as follows :—

Year	Output in tons	Year	Output in tons
1885	1,500	1895	772
1894	1,125	1896	638

In the year 1911 trials were made on apparently parallel lodes in the Old Red Sandstone slates, 400 to 500 yards south of the Derryginagh Mine. These trials, however, seem to have been unsuccessful. Some barytes was obtained, but it was badly stained with specular iron.

Dunmore and **Mountain Common (Duneen Bay, Clonakilty).**
1″ Sheet 201 ; 6″ Sheets Cork 135 S.E. and 144 N.W. & N.E.

The Duneen Bay mines enjoy the reputation of being the greatest producers of barytes in Ireland, and although Dereennalomane, in exceptional years, gave a higher output, it has never been able to maintain its productive supremacy for any lengthened period.

The lodes on which the Duneen mines are situated occur in the Carboniferous Slates, in the townlands of Dunmore and Mountain Common, 3 miles S.S.E. of the town of Clonakilty. In this locality there are two barytes lodes, parallel to each other, and situated some 130 yards apart. Unlike most of the barytes deposits of the south of Ireland they follow the general strike of the country, and are conformable to the

* To accompany Sheets 192 and 199 (1864), pp. 46–7.

cleavage of the rocks in which they occur. Their bearing is accordingly N. 77° E., and their dip 80–85° to the south.

The slates in the neighbourhood of the deposits contain specks of copper and iron pyrites, and are in places stained with the oxidation products of the latter; while in the rocks immediately to the south of the southern lode, stainings of green carbonate of copper are much in evidence.

On the northern or principal lode there is an old opencast working from which a considerable amount of material must have been extracted. The site and extent of this excavation, which is about 40 feet deep, and which extends from the sea-shore inland for a distance of some 300 yards, are indicated on the new 6″ Ordnance map.

The great bulk of the Duneen output, however, appears to have been obtained from the underground workings of this section of the deposit. Mining operations have been conducted here by means of a shaft sunk on the lode to a depth of 350 feet from the surface, with levels driven east and west from it at 10-fathom intervals. Recently a new vertical shaft, 75 feet deep, was sunk by the Liverpool Barytes Co. in the east of the opencast workings; its site is a little to the south of the lode, about 240 yards to the west of the old shaft. The lode is somewhat irregular, but it is on an average about 10 feet wide, swelling in places to as much as 15, or even 20 feet. The difficulties of mining the deposit are considerably increased owing to the acidity of the mine waters. Oxidation of the pyritic minerals of the enclosing rocks give rise to free sulphuric acid and ferrous sulphate, which corrode the pumps and mine pipes, with the result that frequent renewals of this portion of the plant become necessary.

In the townland of Mountain Common, two-thirds of a mile W.S.W. of the Duneen shafts, both daylight and underground workings have been conducted on what is probably the western extension of this lode. Here also are to be seen a great opencast excavation, and the sites of two disused shafts, 100 yards apart, one at each extremity of the cutting. There is available no authentic record with regard to the workings at the older or western shaft, but it is known that the newer one was sunk by the Liverpool Barytes Co. in 1914, to a depth of 120 feet. The lode here is said to consist of from 2–5 feet of very pure barytes. According to the Report of the Department of Mineral Resources for 1916, the output of the Mountain Mine for that year was 814 tons.

In the same line of strike the outcrop of what appears to be the same lode has recently been discovered, 500 yards W.S.W. of the Mountain Mine opencast. This exposure was completely covered up in the summer of 1919, and no indications of the mineral were to be seen here except some

boulders of barytes built into a neighbouring fence. The discovery of this outcrop points to the possibility of a considerable extension of the deposit beyond the limits to which it has hitherto been worked.

At Duneen Bay the southern lode has been worked on a small scale by means of an opencast, extending from the seashore inland for about 100 yards, and of a small shaft, said to have been sunk to a depth of 30 feet. The lode is comparatively narrow, and the barytes is of poor quality. Specimens of the mineral obtained from the spoil-heaps were interspersed with numerous crystals of iron pyrites.

The barytes obtained from the principal workings on the main lode is white, translucent, and coarsely crystalline. In places it is somewhat stained with thin films of limonite, but on the whole, it yields a good proportion of first grade material. In a leaflet issued by the Liverpool Barytes Co., the analysis of a sample of the barytes by G. Watson Gray, of Liverpool, is given as follows :—

Barium Sulphate . . .	98·76
Calcium Sulphate . . .	0·35
Alumina	0·14
Iron Oxide	0·01
Magnesia	Nil
Silica	0·70
Loss, etc.	0·04
	100·00
Specific Gravity . . .	4·44

This sample was presumably from the main lode. The product was marketed under the trade name of " Shamrock Brand."

The first mention of these deposits in geological literature is made by Weaver in his paper " On the Geological Relations of the South of Ireland."* In this paper the author described three beds of sulphate of barytes which he observed on the strand below the northern cliffs of Duneen Bay. Of these the northern bed was 1½ to 2 feet wide, the middle one 4 feet, and the southern one 6 to 8 inches. Three to five feet of slate intervened between the first and second deposits, and twenty feet between the second and third. His description, therefore, does not fit in with the facts of the occurrences as now known, but it is possible that it might have reference to the seaward extension of one of the lodes, broken up into branches in this direction, such as he has represented. The

* Trans. Geol. Soc. London, 2nd Series, vol. v. (1838), pt. 1, p. 25.

occurrence of barytes in this locality was also known to Triphook, who, in 1855, wrote that "the mineral is also found and worked near Clonakilty in this county [of Cork]."* On the 6″ Survey map, prepared in the year 1858, the true positions of the lodes are given, and in a note on the map, apparently referring to the southern deposit, it is stated that the lode was then being worked for material which was exported to England for pottery and glass-making.

Duneen first appears in the Mineral Statistics as a producer of barytes in the year 1876, the deposits being then worked by the Duneen Bay Mineral Co., Ltd. This company continued its activities until 1885, and at this date, apparently, the property passed into the hands of J. Cameron, Swan & Co., of Newcastle-on-Tyne, under whom a steady output was maintained until the year 1902, when the mines closed down. After an interregnum of seven years, the Liverpool Barytes Co. took over the mines in the year 1908. This company continued producing until early in 1918, when, in consequence of the breakdown of the pumping machinery, the workings became flooded. Shortly afterwards the Cookson Barytes Co., of Newcastle-on-Tyne, obtained possession of the property, and the mines are now being worked by this company.

The output of the Duneen mines has been, on the whole, very steady during the entire period of their activity, and the tonnage extracted up to the present amounts to a very considerable total. During the periods 1889–93, 1897–99, and from 1909 onwards, the output has been included with that of the other barytes mines of the Cork district. In the other working years it has been separately returned as follows :—

Year	Output in tons	Year	Output in tons
1876	5,400	1885	6,611
1877	7,060	1886	5,397
1878	8,311	1887	5,739
1879	3,480	1894	5,012
1880	4,113	1895	3,541
1881	3,786	1896	3,953
1882	5,511	1900	5,176
1883	4,158	1901	3,117
1884	1,356	1902	72

The Report of the Department of Mineral Resources gives the output for 1916 at 4,871 tons.

* "On the Occurrence of Sulphate of Barytes in the South West of the County of Cork." Journ. Geol. Soc. Dublin, vol. vi. (1856), p. 224.

Sligo District.

Tormore, Glencarbury, and **Gleniff.** 1″ Sheet 43; 6″ Sheets Sligo 9 N.W. & 6 S.W.

The great barytes lode which traverses the Upper Carboniferous Limestone of the Benbulben plateau is traceable, by occasional outcrops, from the escarpment north of Glencar Lough, through the townlands of Tormore and Glencarbury, to the escarpment at the head of the Gleniff valley, a distance of 1½ miles. It has a general bearing of N. 20° W., and occupies a smooth-walled nearly vertical fissure, underlying sometimes to the west, and sometimes to the east.

In the years 1913–15 the southern part of the lode was explored by the Sligo Barytes Co., Ltd., St. Stephen's House, Westminster, London. These explorations, which were carried out under the direction, first of Mr. Bruce Le Mond, and subsequently of Mr. E. C. Charleton, could not, however, be considered exhaustive; nevertheless, for some reason, the operations ceased in June, 1915. Yet it is certain that an extensive development of the deposit had been contemplated, since, amongst other preparations for dealing with a large output, an aerial ropeway, over half a mile long, had been erected to lower the mineral from the edge of the plateau escarpment to the road on the northern shore of Glencar Lough. From this point it had been proposed to cart the material to Sligo for shipment.

As a result of the explorations the lode has been exposed for examination in several places, and it has now become possible to form a better estimate of the dimensions and quality of the deposit. The trials, which consist of both opencasts and of short adit-levels penetrating the superficial part of the lode, would indicate that there is here a considerable mass of material available for exploitation. The barytes, however, so far as it is exposed, is of low grade, being often badly stained with iron, and in places intermixed with quartz and other impurities.

Going north from Glencar Lake, we see the first outcrop in the face of the escarpment, at the 900-foot contour. Here an adit, 18 yards long, passes through a width of 4 feet 3 inches of quartz stained with iron and green copper carbonate. The lode widens some 30 yards farther north to 6 feet, and then narrows again, within a distance of 150 yards, to 6 inches.

At the next outcrop, 700 yards north of the escarpment, the quartz for the most part gives place to barytes of fair quality. A short adit here proved the mineral over a width of 3 feet, and immediately to the north of the adit the lode swells to 11 feet, dwindling again, however, to 3 feet, within a short distance. Beyond this similar dimensional variations are

repeated, after which the lode becomes temporarily lost. The more northerly of these lenses contains a rib of quartz, 4 inches thick, but otherwise the vein-matter, in both cases, consists of iron-stained coarsely crystalline barytes. The dip of the lode in all this area is slightly to the west.

About 300 yards north of the last-mentioned outcrop, the lode is 9 feet thick, and dips to the east at 80°. Here the barytes is stained in places with iron and green copper carbonate, and the deposit sometimes includes quartz and brecciated limestone.

In the townland of Glencarbury, still farther north, is the site of an old opencast working, close to the western boundary of the townland, at the point where the lode crosses the 1,750-foot contour. In this excavation the lode is 4 feet wide, and consists of barytes similar in character to that of the outcrops already described.

Gleniff Mine. The lode agains outcrops at the boundary between the townlands of Gleniff and Glencarbury, on the edge and face of the magnificent limestone cliff at the head of the Gleniff valley. Here also it is smooth-walled and nearly vertical with a variable underlie, sometimes to the west and sometimes to the east. The lode-matter consists of good coarsely crystalline barytes, slightly discoloured with the rusty stain of limonite, and occasionally containing small quantities of galena and malachite. Although in the old workings the mineral attained in places a width of 7 feet at the breast, the best stoping width, where now worked, is only 4 feet. The barytes, however, is said to pay for extraction down to a stoping width of 2 feet.

Most of the mining operations have been conducted by means of an adit-level driven from the cliff face, a little below the 1,750-foot contour, and penetrating into the mountain for a distance of about 100 fathoms. The mineral has been extracted both by underhand and overhand stoping. From the floor of the level two inclines or winzes were sunk on the lode, at about 20 and 80 fathoms respectively from the mouth of the adit (see Longitudinal Section of the mine, fig. 7). Of these the former passed through a rich body of barytes, which has been stoped down to a depth of 40 feet, over a lateral distance of 50 feet. The shoot pinched out towards the south, but was still 3 feet wide at the bottom of the stope. An attempt is now being made to tap its downward extension by driving from the wall of the cliff, just above the talus slope ; the length of the level necessary to attain this object is estimated at 28 fathoms. From the bottom of the second or southern incline a short level has been driven towards the south, but since the barytes passed through, in both the incline and level, only measured 2 feet across, very little of the mineral has been extracted here. By far the greatest bulk of the output of the mine has been obtained from above

the main level in the neighbourhood of the southern winze, and indeed, the principal mining operations are now confined to this part of the lode. Apparently there is still a lot of material here available for extraction. At the end of the main level, however, the lode narrows down to a mere thread.

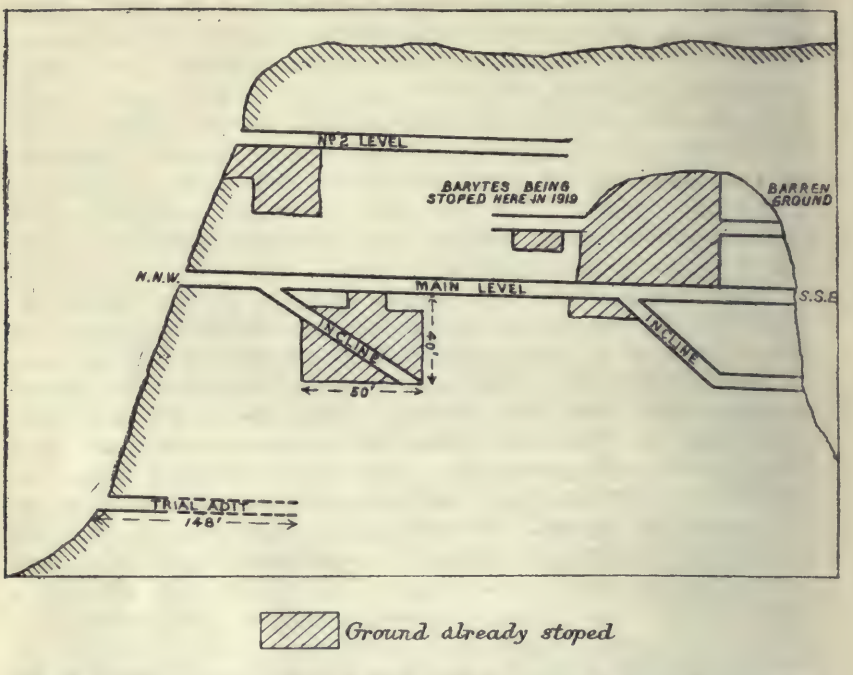


Fig. 7.—Longitudinal Section of Gleniff Barytes Mine, from a rough sketch of the workings.

The workings are very difficult of access. The adit is reached from the top of the great talus slope, which forms such a conspicuous feature round the base of the escarpment, by means of a long ladder placed against the almost vertical wall of the cliff. The barytes is lowered on a wire ropeway, 600 yards long, from the mouth of the main-level to a washing shed, situated in the valley below.

In addition to the workings just described, another adit has been driven on the lode from the face of the cliff, well above the main level. This failed to tap any rich ground, and the only considerable quantity of barytes produced in this part of the mine was obtained from an underhand stope, near the mouth of the adit.

The after-treatment to which the mineral is subjected consists of cobbing, washing, bleaching, and grinding. The cobbing and washing take place at the shed, near the end of the ropeway, the water for the latter operation being supplied by a streamlet coming down from the side of the mountain.

The washed barytes is conveyed by road to the mills, 2 miles lower down the valley, where there is available abundant water-power for the preparation of the finished product. At the mills it is first bleached with dilute sulphuric acid, and after having been dried, is ground to a sufficient degree of fineness to suit the market requirements. The process of bleaching is conducted in a wooden vat. Into this vessel the barytes and acid are introduced, and steam passed through the mixture until all traces of any iron staining are removed. When the bleaching is complete the liquid is drawn off, and the barytes washed free from acid. In the next stages of its preparation the material is thoroughly dried on a drying-floor, and afterwards ground by passing it through a battery of three pairs of stones. The ground material is finally sifted and packed into bags ready for export. All the barytes now produced by the mine is treated in this way, and shipped to Liverpool, from the port of Sligo, for use in the paint industry.

At Gleniff the lode has been mined for nearly half a century, perhaps intermittingly at first, but afterwards continuously, and for many years a steady, though comparatively small, output has been maintained. The Gleniff Mine appears in the Mineral Statistics for the first time in the year 1875, but the output is not specifically included in the returns until 1890, although it is stated in the Geological Survey Memoir* to have been extensively worked by Mr. Barton about the years 1878–9. George L. Tottenham is given as the owner from 1890 to 1894, and Sir Henry Gore-Booth, Bart., of Lissadell, from 1895 to 1911. In 1911 the mine was taken over by the Gleniff Barytes Co., of 25 Bath Street, Glasgow, by whom, under the management of Mr. Thomas Conacher, it is at present being worked. In the official returns the output has sometimes been lumped with that of other Irish localities, but separate figures have been given for the following years :—

Output of the Gleniff Mine.

1894	638 tons	1908	480 tons
1895	634 ,,	1909	610 ,,
1896	300 ,,	1910	399 ,,
1897	1,350 ,,	1911	98 ,,
1900	450 ,,	1912	333 ,,
1901	262 ,,	1913	179 ,,
1902	463 ,,	1914	616 ,,
1903	886 ,,	1915	563 ,,
1904	732 ,,	1916	378 ,,
1905	559 ,,	1917	504 ,,
1906	606 ,,	1918	506 ,,
1907	308 ,,	1919	309 ,,

* Mem. to accompany Sheets 42 and 43 (1885), p. 29.

Another barytes lode is reported to outcrop on the limestone plateau, near the Leitrim border, to the north-east of Gleniff. This is said to have been sunk upon to the depth of 200 feet, but the barytes passed through in the trial pit was only 2 feet wide. It is probably the lode, 1–3 feet wide, marked on the 6″ MS. map of the Geological Survey, at the boundary between the townlands of **Shancrock** and **Mullanfad** (1″ Sheet 43 ; 6″ Sheet Sligo 6 N.E.).

CHAPTER IV.

BARYTES DEPOSITS OF IRELAND (*Continued.*)

Minor Occurrences.

For the sake of completeness it is deemed advisable to collect in this chapter all the remaining records of the occurrences of barytes in Ireland, even though many, if not most, of them are recognised to be of little or no economic value. These occurrences are, nevertheless, of interest in showing the distribution of the mineral, and for their bearing on the theories regarding the age and genesis of barytes deposits.

For convenience of reference the localities are grouped under their respective counties.

Antrim.

Barytes, both alone and associated with quartz, has been found in the joints and fissures of the ancient schists that outcrop in the north of this county. The 6″ Survey maps record its occurrences at Crockan Point, in the townland of **Ballinloughan** (1″ Sheet 8 ; 6″ Sheet Antrim 10 N.W.) ; in the townland of **Tureagh** (1″ Sheet 14 ; 6″ Sheet Antrim 13 N.E.) ; and in the townland of **Falmacrilly** (1″ Sheet 14 ; 6″ Sheet Antrim 14 S.E.). These deposits are probably of no economic importance.

Armagh.

Creggan Duff. 1″ Sheet 70 ; 6″ Sheet Armagh 31 N.W.

Half a mile north-east of the hamlet of Creggan, a lode, bearing N. 20° E., and dipping at 70° towards the west, traverses the Silurian slates and grits in this townland. The deposit consists of galena and pyrites in a gangue of barytes and quartz. Good bunches of lead ore are said to have been obtained in the workings on this lode, but there is no information available with regard to the quantity or quality of the barytes.

Cavan.

Cornurney and **Tonyin.** 1″ Sheet 69 ; 6″ Sheet Cavan 22 N.E.

Three miles south of Cootehill a north and south lode, carrying galena, associated with earthy oxide of manganese, and arsenic and antimony sulphide ores, crosses the boundary between the townlands of Cornurney and Tonyin. The gangue minerals are quartz and calcite, with occasionally a small quantity of barytes. The lode traverses the Silurian slates and grits.

Clare.

Addergoole. 1″ Sheet 124 ; 6″ Sheet Clare 18 N.W.

According to the Survey Memoir to accompany Sheets 124 and 125 (p. 45), " flying veins of sulphate of baryta were noted in one or two places [apparently in the townland of Addergoole, 2 miles north of Crusheen], but none worthy of special record." These deposits occur in the Carboniferous Limestone.

Ballyvergin. 1″ Sheet 133 ; 6″ Sheet Clare 26 S.E.

On a lode traversing the Lower Carboniferous Limestone rocks in this townland is the site of the old workings of the Ballyvergin mine. The lode, which bears N. 10° E., and dips to the west at 45–70°, yielded lead, copper, and sulphur ores. A small quantity of barytes was found associated with these minerals.

Caher. Ballyhurly, and **Ballynagleragh.** 1″ Sheet 134 ; 6″ Sheet Clare 29 S.W. & S.E.

Barytes in association with galena occurs in many places in the Silurian rocks in these townlands. Trials were made on the deposits in Caher and Ballyhurly, but apparently without success (see Memoir to accompany Sheet 134, p. 43).

Carrowbaun and **Carrownakilly.** 1″ Sheet 134 ; 6″ Sheet Clare 37 N.W.

It is stated in the Survey Memoir to accompany Sheet 134 (p. 43) that " numerous flying veins of sulphate of baryta, with specks and strings of galena, occur in the rocks that appear in the river half a mile west of Annacarriga." The site referred to in the Memoir is apparently the bed of the river at the boundary between the townlands of Carrowbaun and Carrownakilly, since, in the Silurian grits and slates here, the 6″ Survey map records the occurrence of lead ore disseminated through 20 feet of the bedding.

Cork.

Killoveenoge and **Rooska.** 1″ Sheet 199 ; 6″ Sheet Cork 117 S.E.

In the townlands of Killoveenoge and Rooska, 4 miles W.S.W. of Bantry, a lode traversing the copper horizon of

the Old Red Sandstone was formerly worked for barytes and lead. In the year 1850 the mine temporarily closed down, but from the Mineral Statistics List of Mines it would appear that it was subsequently re-opened by the Bantry Bay Barytes Co., by whom it was worked from 1875 to 1879. The lode follows the general strike of the country, i.e., E. 15° N. to W. 15° S., and is traceable for about a mile. No information is available to indicate the extent to which barytes occurs in the deposit.

Dunbeacon. 1″ Sheet 199 ; 6″ Sheet Cork 130 S.E.

At Dunbeacon, half a mile W.S.W. of Dereennalomane Mine, a barytes lode bearing N. 65° W. was worked to a small extent by the British Barytes Co., in the years 1872–4. In the workings carried out by this company, a shaft was sunk to a depth of 10 fathoms, and short levels were driven on the lode from the bottom of the shaft. The barytes at the breast varied in width from 6 inches to 18 inches. The lode occurs in the Kiltorcan beds.

Dereennalomane. 1″ Sheet 199 ; 6″ Sheet Cork 131 S.W.

In addition to the great deposit which has been so extensively worked, two other barytes lodes outcrop in this townland, about half a mile to the east of the mine. In 1919 trials were made on these deposits ; the lodes were found to be much broken and altogether unpromising.

Barryroe. 1″ Sheet 199 ; 6″ Sheet Cork 131 N.E.

A barytes lode, running east and west, and cutting the copper horizon of the Old Red Sandstone series, occurs at Barryroe, nearly two miles south of Durrus Railway Station. Some trials, which were made by trenchings here and there along its outcrop for a distance of about 40 yards, disclosed some good white barytes. The lode is not now visible in any of the excavations, and there is no information regarding its dimensions. A heap of white and bluish-grey barytes, extracted during the trials, is still lying at the surface.

Gortnamona. 1″ Sheet 199 ; 6″ Sheet Cork 140 S.W.

At Gortnamona, a third of a mile S.E. of the Skull Union Workhouse, is seen the site of an old shaft marked " Barytes Mine " on the 6″ Ordnance map. No barytes, however, could be found in the spoil-heap near the workings. Writing about 1860, G. H. Kinahan states * that copper had been found in this and in the adjoining townlands, but that no mining operations were then being carried on. He makes no mention of the presence of barytes in the deposits.

Ballycummisk. 1″ Sheet 199 ; 6″ Sheet Cork 140 S.W.

A series of nine copper lodes appears in the Old Red Sandstone rocks in this townland. According to G. H. Kinahan,

* Geol. Sur. Mem. to Accompany Sheets 200, 203–5, and 199 (1861), p. 24.

the eighth from the south contained quartz, barytes, micaceous iron, and yellow copper. He states * that "this lode is the principal one in the 'sett,' as it is of greater magnitude, and contains very rich ore, but the latter is deteriorated by the baryta, as it is impossible by washing to separate them. Captain Pope [who was in charge of the mining operations] thinks the lode is improving as they go down, and at the sixty-one fathom level there was less baryta than at the fifty-one fathoms."

This appears to be a true fissure-lode containing copper pyrites as the principal ore, with barytes and quartz as the gangue minerals.

Little Island. 1″ Sheet 200; 6″ Sheet Cork 143 N.E.

The 6″ Survey map records a barytes vein as occurring in the Old Red Sandstone rocks at Clogna Head, 2½ miles S.E. of the town of Rosscarbery. It is described as a vein of mottled white and grey barytes with specular iron, and as having small cavities filled with fibrous malachite. The dimensions of the deposit are not stated. It apparently follows the strike, and is conformable to the cleavage of the country rock. Smaller veins of barytes, associated with quartz, are stated to occur to the south of this deposit.

Aghatubrid, &c. 1″ Sheet 200; 6″ Sheets Cork 142 N.E. and 143 N.W. & N.E.

The great manganese channel of Aghatubrid runs east and west for about 5 miles, from Glandore Harbour, passing through the townlands of Aghatubrid, Maulagow, Gortyowen, Kilbeg, Knockarudane, Rouryglen, Ballyvireen, and Derry, where it becomes temporarily lost. After having been shifted to the south by a fault, it reappears near the town of Rosscarbery, and then runs through the townlands of Burgatia and Bohonagh, beyond which it is no longer traceable. The lode cuts the bedding and cleavage at a small angle; it is peculiar, inasmuch as it appears to fill no regular fissure with definite walls, but is much broken, and intermixed with the country rock. Like the majority of the barytes lodes of the Cork district, it cuts the copper horizon, but differs from them in persisting in its course far into the lower beds of the Old Red Sandstone series.

The deposit has been worked for iron and manganese, these materials being present respectively in the form of haematite and psilomelane (a mineral containing the element barium). Barytes, quartz, and copper ores have been found in the lode in association with the principal minerals. The amount of barytes present, however, is comparatively small, and of no economic value.

* Ibid.

Spanish Cove and **Callaros Eighter.** 1″ Sheet 204 ; 6″ Sheet Cork 147 S.E.

In these townlands a copper lode appears in the Old Red Sandstone series, about one mile north of Crookhaven. It underlies to the south, and bears N. 65°E., i.e., in the direction corresponding to the general strike of the country. The Geological Survey memoir * states that it contains copper pyrites and heavy spar. There is no other information available regarding the deposit.

Donegal.

Fintown. 1″ Sheet 15 ; 6″ Sheet Donegal 66 N.E.

Fintown is given as a locality for barytes in the list of minerals for County Donegal compiled by Robert H. Scott, and subsequently published in the Journal of the Royal Dublin Society (vol. iv., 1866, pp. 114–125). The record was verified by a committee of the British Association of 1861–2. Apparently the occurrence of barytes referred to is that forming the gangue of the lead-zinc lode at Loughnambraddan. This lode is found in the Metamorphic series.

Fintown. 1″ Sheet 16 ; 6″ Sheet Donegal 67 N.W.

In the year 1916 Captain Alan Smythe, of 57 Leeson Park, Dublin, reported the discovery of a barytes lode in the east of this townland, at the angle between the main road and the bye-road leading to the old lead mine at Glenaboghil. It was exposed in a drain, since filled in, about 200 yards west of Mill Bridge. The barytes, which, according to Captain Smythe, occurs in considerable quantity, is pure, but of a creamy colour. The lode traverses the Metamorphic series.

Abbeylands. 1″ Sheet 31 ; 6″ Sheet Donegal 107 N.W.

At Abbeylands, about a mile N.W. of Ballyshannon, a lead mine was worked rather extensively in the middle of the last century ; it was not abandoned until the year 1862. The lode on which the mine is situated occurs in the Lower Carboniferous Limestone. Since the ground here is covered with drift there is nothing to indicate its bearing, or its relations to the country rock. The deposit consisted of galena, with barytes as the gangue mineral. The latter, though of good white colour, contained disseminated crystals of galena, which, of course, detracted from its commercial value. According to information obtained from an old miner, aged 90 years, some 300 to 400 tons of the barytes were brought to grass, but never sold.

Where the pits were sunk on the lode is now tilled ground, the dumps having been removed and all traces of the workings

* Memoir to Accompany Sheets 200, 203–5, and 199 (1861), p. 23.

obliterated. Fragments of galena and barytes can still be picked up in the laneway which runs through the site of the workings.

Barytes occurs also in numerous small veins in the grey limestone, 2 miles west of Ballyshannon (6″ Sheet Donegal 106 S.E.). None of these is likely to be of economic importance.

Down.

Conlig and **Whitespots.** 1″ Sheet 37 ; 6″ Sheet Down 6 N.W.

From the early part of the last century up to the year 1865 a lode was actively mined for lead ore in the townlands of Conlig and Whitespots, three-quarters of a mile due north of the town of Newtownards. Cutting the Silurian slates and grits, it bears N. 15° W. for 500 yards at its southern end, and then swings round towards the north, running in the direction N. 3° W. for the remainder of its course. The gangue of the lode consists of brecciated country rock in a pale grey felspathic matrix, through which run strings of barytes containing crystals of galena, and small quantities of copper pyrites and peacock copper ore.* If, however, the material in the spoil-heaps is to be taken as a criterion, barytes must have formed but a very unimportant constituent of the deposit where it was worked.

In some of the open trial pits on the outcrop of the lode strings of barytes can be seen penetrating the slates and grits.

Guns Island. 1″ Sheet 49 ; 6″ Sheet Down 39 S.W.

Guns Island, which is situated close to the mainland, 3 miles N.E. of Ardglass, is included by Kinahan in his list of barytes localities.† This authority remarks that the mineral is associated with copper and lead in the Ordovician rocks. The 6″ Survey map merely mentions the occurrence of some small barytes veins in the southern part of the island.

Rathmullan Upper. 1″ Sheet 61 ; 6″ Sheet Down 44 N.E.

A lode which cuts across the Silurian rocks in Rathmullan Upper was formerly mined for lead at Glebe House, near the southern boundary of the townland. Barytes and fibrous gypsum form the gangue of the lode, but there is nothing to indicate that the former mineral occurs in quantity.

Killough. 1″ Sheet 61 ; 6″ Sheet Down 45 S.W.

The Geological Survey Memoir‡ mentions the occurrence of barytes immediately to the south of the village of Killough. Here, running N. 30° W., and cutting the bedding of the

* Geol. Survey Memoir to Accompany Sheets 37, 38, and 29 (1871), p. 43.
† Journ. R. Geol. Soc. Ireland, vol. viii. (1889), p. 39.
‡ Memoir to accompany Sheets 49, 50, and 61 (1876), p. 55.

Silurian rocks at right angles, is a basalt dyke, visible only at low water; it extends for about 350 yards from near the old barracks towards the Perch Rock. This dyke is 18 feet wide, and contains "two longitudinal veins of heavy spar, each from 6 to 12 inches wide, with slight traces of iridescent copper, and iron pyrites." The deposit is apparently of no economic value.

Dromore (vicinity of). 1″ Sheet 71; 6″ Sheets Down 51 S.W. & 54 N.W.

Kinahan* includes, in his list of barytes localities, the "vicinity of Dromore," which, from the sheet numbers given by him, must refer to the townland of that name, near Warrenpoint. He states that the barytes is found here in the Ordovician in association with lead. The 6″ Survey maps, however, do not record the occurrence of the minerals in this district. Griffith,† on the other hand, gives the "vicinity of [the town of] Dromore" (1″ Sheet 48; 6″ Sheets Down 21, etc.) as a locality for lead and manganese, though he does not say if barytes is associated with them. It is possible that Kinahan confused the town with the townland of the same name. There seems to be no further record of the occurrence.

DUBLIN.

Portraine (Portrane) Demesne and Quay. 1″ Sheet 102; 6″ Sheets Dublin 8 S.E. & 12 N.E.

Professor Seymour records‡ the frequent occurrence of barytes in the older Palaeozoic strata of Portrane. He informs the writer that the mineral is found in irregular veins of about 2 inches thick, penetrating the andesitic rocks which are associated with the Ordovician (Lower Silurian) deposits of the promontory.

Balseskin. 1″ Sheet 112; 6″ Sheet Dublin 14 N.W.

Several veins of barytes, up to 6 inches thick, occur in the joints of the Carboniferous Limestone, in the Old Red Lion quarry, situated in the townland of Balseskin, 2 miles N. by W. of Finglas.§ The barytes is described as of good quality.

Howth. 1″ Sheet 112; 6″ Sheet Dublin 16 S.W.

Barytes has been recorded from the vicinity of Howth, but the exact locality of its occurrence is not stated. It is probable, however, that the source of the mineral is the gangue of the lead lode which traverses the Cambrian rocks, near the eastern shore of the peninsula.

* Journ. R. Geol. Soc. Ireland, vol. viii. (1889), p. 39.

† Journ. Geol. Soc. Dulbin, vol. ix. (1862), p. 144.

‡ Handbook to the Dublin District (prepared for the meeting of the British Association, 1908), p. 57.

§ Geol. Survey Memoir (Drift Series): The Geology of the Country Around Dublin (1903), p. 130.

Dalkey. 1″ Sheet 112 ; 6″ Sheet Dublin 23 S.E.

In the granite on the southern shore of the townland of Dalkey Commons, near where Sorrento Terrace now stands, is a lode upon which small workings were opened some 150 years ago. The ores which it carries are galena and zinc-blende, with quartz and barytes as the gangue minerals.* Robert Mallet describes † the gangue as consisting almost entirely of barytes in the massive crystalline form, and nearly milk-white in colour. The mineral contains sensible traces of strontium.

Various observers have noted other small veins of barytes in this locality, and also at Rochestown Hill, and at Victoria Park, Killiney.

Ballycorus and **Rathmichael.** 1″ Sheet 121 ; 6″ Sheet Dublin 26 S.W.

A lode traversing the granite and mica-schist, and bearing W.N.W., was formerly worked for lead in these townlands. The vein, which varies from 1 to 2 feet in width, contains galena, zinc-blende, and in places, native silver. Barytes and quartz are the gangue minerals.

Galway.

Griggens. 1″ Sheet 94 ; 6″ Sheet Galway 25 N.E.

The Geological Survey Memoir‡ states that in the valley south-east of the road leading from Maum to Loughnafooey, in this townland, there is a N. 40° W. lode, containing barytes. On the re-examination of the deposit in 1919, however, it was proved to consist not of barytes, but of an intimate mixture of quartz, calcite, and siderite, having a specific gravity of 2·9. At its widest the vein is not more than one foot thick, and in places it is much broken up into strings and lenses. Many other similar veins and strings are found also in the neighbourhood. The deposits weather with an ochreous skin.

Clooshgereen and **Cregg.** 1″ Sheet 105 ; 6″ Sheet Galway 54 S.W.

A considerable metalliferous vein, known as the Champion Lode, bearing N. 66° W. and underlying towards the south, cuts the gneissic rocks at the boundary between the townlands of Clooshgereen and Cregg. While copper pyrites, iron pyrites, and galena are the principal minerals, it contains barytes also in great bunches. In the townland of Cregg, the lode was proved in the mining operations for a distance of 350

* Notes on the Mineralogy of Parts of the Vicinity of Dublin ; Fitton and Stephens, London (1812), p. 14.

† Journ. Geol. Soc. Dublin, vol. x. (1864), p. 70.

‡ Memoir to Accompany Sheets 93 and 94 (1878), p. 162.

yards, where it attains a width of over 8 feet at its south-western end. The workings at Clooshgereen were not so extensive, but it was here that barytes occurred in greatest abundance. Where it was found in mass, it is stated to have been intermixed with long crystals of milky quartz. Fragments of good clean milk-white barytes may still be picked up on the ground near the site of the old shaft.

Bunnaconeen. 1″ Sheet 95 ; 6″ Sheet Galway 42 N.W. & S.W.

This locality, which is situated about 1½ miles N.E. of Headford, is given by Kinahan in his list of barytes lodes. There is no further record of the occurrence of barytes here, and the existence of the deposit is extremely doubtful. The ground is heavily covered with drift, and the underlying rock is not exposed in any part of the area. Within the memory of the oldest inhabitants no such mineral has ever been found in the locality.

Canrawer and **Claremount.** 1″ Sheet 95 ; 6″ Sheet Galway 54 N.W. & S.W.

To the north-west of the Bag Factory, near the boundary between these townlands, occurs an almost N. and S. lode containing barytes, iron pyrites, and galena. Barytes was found also in a trial on the underlie of the lode, a little to the south-west of O'Fflahertie's Shaft. These deposits occur in the granite and in the gneiss respectively.

Glengowla. 1″ Sheet 95 ; 6″ Sheet Galway 54 S.W.

Near the margin of Lough Ateeaun, in Glengowla East, a lode, which traverses the Metamorphic series, was formerly worked for lead. It bears N. 87° W., and underlies to the south. The gangue is mainly calcite, but it also contains some barytes, fluor-spar, and quartz. The Survey Memoir * states that a few tons of barytes were raised from this mine and shipped from Galway.

Floyd's Lode, situated in Glengowla West, about 800 yards to the west of Glengowla Mine, contains the same association of minerals. The lode is 2 feet wide, is vertical, and bears N. 50° W.

In the returns given in the Mineral Statistics for 1882, Oughterard, Co. Galway, is credited with an output of 149 tons of barytes. There is, however, nothing to indicate from which of the mines in the neighbourhood the mineral had been raised.

Inveran and **Minna.** 1″ Sheet 113 ; 6″ Sheet Galway 91 S.W.

A copper and lead lode, cutting the granite, was formerly worked in these townlands, on the coast north of Travore

*Memoir to Accompany Sheet 95 (1870), p. 66.

Bay. The gangue consists of quartz with a little barytes, fluorspar, and calcite.

Kildare.

Knockaulin, Glebe North, and **Moortown.** 1″ Sheet 120 ; 6″ Sheet Kildare 28 N.E. & S.E.

The Geological Survey Maps record the occurrence of veins of barytes in the massive green grits of the Ordovician (Lower Silurian), in these townlands.

Leitrim.

Magheramore. 1″ Sheet 43 ; 6″ Sheet Leitrim 3 S.E.

A note on the 6″ Survey Map records indications of barytes in the escarpment of the Upper Carboniferous Limestone, near the southern boundary of the townland of Magheramore.

Limerick.

Dromeliagh. 1″ Sheet 144 ; 6″ Sheet Limerick 14 N.E.

A barytes lode, occurring in the Lower Carboniferous Limestone, is exposed in a large quarry in this townland, south-west of the bridge over the Mulkear River.* It bears N. 80° W., and dips towards the south at 75°. The size of the lode is not stated in the Survey Memoir, but it is presumably small.

Oolahills. 1″ Sheet 154 ; 6″ Sheet Limerick 25 S.W. & S.E.

At Oolahills barytes forms part of the gangue of a great metalliferous vein, which has been worked principally for copper and lead. The mode of occurrence of the barytes will be appreciated from the following description of the deposit in the Geological Survey memoir :† " The principal lode has a nearly east and west bearing, underlying [dipping] to the north at from 85° to 90°. This lode is visible at the surface in a quarry on the side of the hill, about 500 yards north-east of the R.C. Chapel. It is here from fifteen to twenty feet wide, and is a very hard whitish blue trappean-looking rock, full of minute specks of iron pyrites. Through this run nearly vertical veins of sulphate of baryta, which is usually the gangue of the ores. This lode may be traced for three-quarters of a mile to the east, where several shafts have been opened on it, but never to any great depth. They are now abandoned, and the workings were only carried on at the western end when this mine was visited in June, 1859 ; copper pyrites, galena, barytes, and iron pyrites were then being raised.

* Geol. Survey Memoir : The Geology of the Country Around Limerick (Drift Series) (1907), p. 16.

† Memoir to Accompany Sheet 154 (1861), p. 28.

"In some of the black shales associated with the main lode are small veins of sulphate of baryta, which sometimes contains a little mundic and galena."

These deposits occur in the Lower Carboniferous Limestone.

Londonderry.

Glenconway. 1″ Sheet 18 ; 6″ Sheet Londonderry 16 S.W.

Irregular veins of calcite, mixed with quartz and barytes, are shown in the 6″ Survey map traversing the Metamorphic limestone and talcose schists, in the townland of Glenconway, 4½ miles N.W. of Dungiven. These deposits are exposed here in a large quarry ; they are apparently of no economic value.

Teeavan. 1″ Sheet 18; 6″ Sheet Londonderry 30 N.E.

Irregular veins of barytes, about 6″ wide, traverse the schistose and gneissic rocks (altered Silurian) in the northern part of this townland. The barytes is associated with quartz.

Fallagloon. 1″ Sheet 19 ; 6″ Sheet Londonderry 36 N.W.

Portlock, in the geological map attached to his report,* notes the occurrence of barytes at the south-western boundary of Fallagloon, 3½ miles W.N.W. of the town of Maghera. In the text † he refers to the deposit as occurring in the [Lower Carboniferous] conglomerates in immediate connection with the mica-schist. He makes no statement regarding the dimensions of the deposit.

Straw. 1″ Sheet 26 ; 6″ Sheet Londonderry 40 N.E.

In the north of the townland of Straw, one mile due west of Draperstown, a small barytes lode, traversing the Calciferous Sandstone, outcrops on the right bank of the Moyola River. It bears N. 40° W., and is about 10″ thick. The barytes is of a good white colour.

Derrynoyd. 1″ Sheet 36 ; 6″ Sheet Londonderry 40 N.E.

In this townland, also in the Calciferous Sandstone, is the site of an old barytes mine, which, however, appears to have been worked only in a very small way. The barytes in the spoil-heap, near the pit, is stained red, and is much mixed with red conglomerate and sandstone. Straw and Derrynoyd probably correspond with the Ballinascreen locality of Portlock.

Cavanreagh. 1″ Sheet 26 ; 6″ Sheet Londonderry 40 S.W.

This locality appears in Kinahan's list of barytes lodes, and a note on the 6″ Survey map indicates the position of a

* Geological Report on Londonderry, and Parts of Tyrone, and Fermanagh. Dublin, 1843.

† Ibid, p. 514.

barytes vein, at the fork of the stream, one mile west of Cavanreagh House. On the re-examination of the deposit in 1919, however, it was found to consist, not of barytes, but in the main of carbonate of iron. It bears N. 40° W., and is only 6 inches thick where it crosses the stream.

Carncose. 1″ Sheet 27 ; 6″ Sheet Londonderry 46 N.W.

The 6″ Survey map describes a vein, 2 feet wide, consisting of barytes associated with red ferruginous matter, in the Metamorphic series, 200 yards N.N.W. of Carncose Rock. This vein bears N. 10° E., and dips towards the west at 60°.

Derryganard. 1″ Sheet 27 ; 6″ Sheet Londonderry 46 N.W.

A trial for iron on a N.W. lode in the granitoid rocks here disclosed some pure haematite in a gangue of barytes.

Tintagh and **Letteran.** 1″ Sheet 27 ; 6″ Sheet Londonderry 46 N.W.

On the eastern slope of Tintagh Mountain, a thin vein of barytes is shown on the 6″ Survey map, traversing the Metamorphic series, south of the basaltic escarpment. Barytes veins outcrop also in the stream at the boundary between the townlands of Tintagh and Letteran, 350 yards N.W. of Fairview House.

Cranny. 1″ Sheet 27 ; 6″ Sheet Londonderry 46 N.E.

In this townland a brecciated lode consisting of red haematite and barytes is exposed in a stream, 250 yards W.N.W. of Glenview House. It is about 7 feet wide, and occurs in metamorphosed schists of Silurian age. The barytes is badly stained with iron, and appears to be of no economic value. Barytes veins were met with also in a well, 300 yards N. of Glenview House, and in the rocks exposed in the neighbouring stream.*

Quilly and **Tullynagee.** 1″ Sheet 27 ; 6″ Sheet Londonderry 46 N.E.

Barytes occurs in the highest beds seen in the stream which passes 400 yards north of Lower Town,† presumably at the boundary between the townlands of Quilly and Tullynagee. The rocks consist of light-red conglomerates belonging to the Lower Carboniferous series.

Louth.

Knockatober. 1″ Sheet 81 ; 6″ Sheet Louth 18 S.W.

In the eastern part of this townland veins of barytes were exposed in a quarry excavated in the Gotlandian (Upper Silurian) slates and grits,

* Geol. Survey Memoir to Accompany Sheet 27 (1881), p. 10.
† Ibid, p. 16.

Coolartragh. 1″ Sheet 58 ; 6″ Sheet Monaghan 14 N.E. & S.E.

Sir Richard Griffith states* that the mines situated in this townland yielded argentiferous galena, with zinc and sulphate of barytes ; and Kinahan, no doubt on Griffith's authority, includes the townland in his list of barytes localities. The lode which has been worked here is probably the northern extension of the well-known Tassan Lode, even though its gangue minerals in the neighbourhood of Tassan Lough are stated to be chiefly quartz and calcite. It occurs in the Upper Silurian (Gotlandian).

Carrickagarvan and **Cornalough.** 1″ Sheet 70 ; 6″ Sheet Monaghan 25 N.W.

In these adjoining townlands, about 2 miles south of Castleblayney, occurs a series of three parallel lodes cutting the Silurian grits and slates. They bear about N. 20–25° W., but the principal one, known as the Hope Lode, forks towards the south, and both branches swing into a more southerly course. The lodes yield argentiferous galena, and this is associated with barytes, chlorite, and quartz.

Carrickartagh. 1″ Sheet 70 ; 6″ Sheet Monaghan 27 S.E.

Traversing the Silurian rocks at the western margin of 1″ Sheet 70 is a deposit of barytes on which some trials have been made. About the year 1898, a pit is said to have been sunk on it to a depth of 16 feet, by the late E. Shirley, Esq., of Lough Fea, and about 50 tons of barytes were extracted. This pit was re-opened in 1919 by the Farney Development Co. Two lodes appear to cross at the site of the pit, the principal one bearing N. 15° W., and a counter lode W.N.W. A bunch of barytes, 7 feet thick, occurs at the junction of the lodes where they outcrop, and this is said to increase in depth to the width of 10 or 12 feet.

The barytes is pure white, and is coarsely crystalline ; it gives the following analysis :—

Barium Sulphate . . .	98·38
Iron Oxide	·03
Alumina	·07
Calcium Sulphate . . .	Trace
Silica	·65
Water, etc.	·87
	100·00

The mineral, however, is in places contaminated with small quantities of galena.

* Fossil and Mining Localities : Journ. Geol. Soc. Dublin, vol. ix. (1862), p. 150.

Queen's County.

Dysartenos. 1″ Sheet 128; 6″ Sheets Queen's County 13, 14, 18 & 19.

A specially prepared list of the economic mineral deposits of Ireland was handed in by Professor Hull to the Select Committee of Industries (Ireland)*, which sat in the year 1885. In this document Dysartenos is given as one of the localities for barytes, the only other barytes deposit mentioned being that of Benbulben, Co. Sligo, and both are described as "good; formerly worked."

There appears to be no other authority for the existence of a barytes deposit at Dysartenos. At any rate, nothing is now known about it.

Tipperary.

The most important barytes deposits in this county are found in the Silvermines area, about 6 miles S.S.W. of the town of Nenagh. They are of three distinct types, according as they occur (1) in the Old Red Sandstone and Silurian formations, (2) in the great fault-fissures between the Carboniferous and the older Palaeozoic rocks, or (3) in the beds of the Carboniferous Limestone. The different types will be referred to under their respective localities.

Shallee and **Lackagh.** 1″ Sheet 134; 6″ Sheet Tipperary 26 S.W.

In the townlands of Shallee and Lackagh the Old Red Sandstone capping the core of the Silvermines Mountains is traversed by numerous veins, consisting of argentiferous galena, usually in a matrix of barytes. The veins occur mostly in groups, the members of which are often very close together, in places only a few feet apart. Viewed as a whole, the vein-system shows a radial arrangement, but there is a local parallelism between the members of the same group.

The Shallee East stopes are about 20 in number, and are mostly opencast workings, though a few of the lodes have been mined in depth. The vein-matter varies in width from 2 feet downwards, and the lodes, which are nearly vertical, bear N. 15° W.

At Shallee West about 14 of the veins have been worked at the outcrops to an average depth of about 5 fathoms. The workings vary in width from 3 to 6 feet, and some of them extend for a lateral distance of 80 yards. In the southern part of the area the lodes have a general bearing N. 60° W., but in the north they are variously oriented from N. 70° W.

* Report: Industries (Ireland) (1885), p. 832.

to N. 60° W. The barytes is opaque to semi-transparent, and of a whitish-grey or brownish colour.

Similar veins appear in the Old Red Sandstone in the north of the townland of Lackagh, and at the face of the escarpment here a few of them have been worked in a small way. These also are vertical, and have a bearing which varies from N. 75° W. to N. 25° W.

As regards their barytes-content the lodes of Shallee East differ notably from those of Shallee West and Lackagh. In the former group the gangue consists of a mixture of barytes and quartz, while in a few instances the gangue is practically absent; in the latter, on the other hand, barytes is the predominating mineral.

In addition to these deposits the 6″ Survey map notes the occurrence of three or four barytes lodes at the boundary between the townlands of Goulreagh and Shallee West, and of a similar vein crossing the north-western boundary of the former townland. No further particulars of the deposits are given.

Gorteenadiha and **Garryard.** 1″ Sheet 134; 6″ Sheet Tipperary 26 S.W.

In the townland of Gorteenadiha a great ramp or lode occupies the fault-fissure at the junction of the Old Red Sandstone and Carboniferous Limestone series. The lode, which is enclosed between ill-defined walls, is really a mineralised shatter-belt, consisting of a hard quartzose breccia, interspersed with copper ore, iron pyrites, and galena. At its widest part it is 40 feet between the walls, or about 24 feet on the average, and it is traceable here for at least a distance of half a mile. Barytes occurs in the breccia, but probably not in sufficient mass, nor of sufficient purity, to pay for extraction.

The lode re-appears farther east at Garryard, and here also it consists of a brecciated mass of sandstone with quartz and barytes, through which the ores are distributed.

Gortshaneroe and **Knockanroe.** 1″ Sheet 134; 6″ Sheet Tipperary 26 S.E.

Towards the eastern boundary of the townland of Gortshanroe barytes, in association with galena, occurs in the dolomitised beds of the Carboniferous Limestone. The barytes takes the form of great tabular crystals, milk-white in colour, though in places somewhat stained with limonite.

Near the western boundary the limestone is similarly mineralised, and in the two streams going north from the Knockeen and Ballynoe mines, a bed consisting mostly of grey-coloured barytes, in association with pyrites, orpiment, and other minerals, is exposed. In these cases the barytes bodies are not fissure or open-space deposits, but have been

formed indirectly by the metasomatic replacement of the limestone (see Chap. V., p. 60).

Weaver* called attention to the occurrence, apparently in the Silurian slates, south of Knockeen, of three parallel veins containing quartz, heavy spar, galena, blende, and pyrites. There is a good deal of uncertainty regarding the identity of these lodes, but it is probable that two of them are definitely located by the sites of old workings, viz., one 300 yards south, and the other 900 yards south-east of Knockeen Mine. Fragments of galena and barytes have been found near the mouths of old pits on these workings.

Farther east, at Knockanroe, the lode occupying the junction fault re-appears at the surface. This is the powerful vein mentioned by Weaver, which he described as "consisting at the surface principally of quartz and iron pyrites, with some heavy spar, galena and blende."†

Bohernarude, Borrisnoe, and **Mien.** 1″ Sheet 135; 6″ Sheet Tipperary 23 S.W.

The 6″ Survey map notes the occurrence of veins of barytes in the Silurian slates and grits at the boundary between the townlands of Bohernarude and Borrisnoe; and again, of strings of the mineral in the Old Red Sandstone rocks at the boundary between the latter townland and the townland of Mien. The deposits appear to be of little importance.

Lackamore. 1″ Sheet 144; 6″ Sheet Tipperary 38 N.W.

Barytes forms part of the gangue of the copper lode at Lackamore, but the extent of its occurrence here is insignificant. The lode occurs in the Ordovician.

Glenough, Foilmacduff, and **Turraheen Lower.** 1″ Sheet 145; 6″ Sheets Tipperary 45 S.E. & 46 N.W.

Describing the minerals of these localities, the Survey Memoir‡ states that: "Sulphate of barytes occurs in thick dyke-like masses, and in small veins in many of the Silurian grits; and whenever it has been observed it re-appears pretty frequently within a limited area. Some of these hard Silurian grits present the appearance of a tangled mass of such small veins or strings cutting each other at all angles. This mineral has also been found at the following localities. At Glenough, in a ravine situated on the east side of the stream, and somewhat less than a mile and a quarter due north of Poulanass Waterfall, where it occurs as a vertical vein, bearing E. and W., and having a thickness of two feet three inches near the source of the Glashanashagh river, a tributary to the Multeen.

* Geological Relations of the East of Ireland. Trans. Geol. Soc. Lond. (1819) vol. v. pt. i., p. 243.

† Ibid.

‡ Memoir to Accompany Sheet 145 (1860), p. 31.

"In strings in some slaty shales by the south side of the last-named river, where it runs through a narrow defile in the townland of Turraheen Lower.

"In a coomb about a mile south of the mining village at Hollyford, and in other places in small quantities."

The 6″ Survey map shows a second barytes vein, 18 inches thick, outcropping in a stream at Glenough Lower. The coomb deposit mentioned above is represented on the same map as a north and south vein, penetrating brown and variegated grits in the townland of Foilmacduff.

Barytes has been observed also in several places underground in the workings on the Hollyford Lode, though apparently not in quantity.

Tyrone.

Glasmullagh, Cashty, and **Cloonty.** 1″ Sheet 25; 6″ Sheet Tyrone 25 N.W.

It is stated* that one of the faults "crossing the S.W. shoulder of the hill, Bessy Bell, is accompanied by a deposit of barytes, near to where the fault cuts the main road from Newtown Stewart to Omagh, which also crosses this shoulder of the hill." The deposit here referred to is, no doubt, that occurring at the boundary between the townlands of Cashty and Cloonty. In this locality the gneiss is broken by a fault, and the brecciated fragments of the rock are re-united by a cement of quartz and barytes.

In the townland of Glasmullagh, 500 yards to the south-east, the 6″ Survey map notes an exposure of gneiss the joints of which are filled with barytes, and that there are large lumps of the mineral scattered through the fields in the vicinity. This exposure is no longer visible, its site being now occupied by a flax-pool, but numerous lumps of barytes lying about on the surface bear evidence to the proximity of a deposit of the mineral.

A small vein of barytes appears also in the gneiss, one mile N.N.W. of Glasmullagh, at the boundary between the townlands of Ballyrenan and Aghafad.

Cluntyganny. 1″ Sheet 27; 6″ Sheet Tyrone 29 N.E.

Here, according to a note on the 6″ Survey map, a vein of barytes appears in the metamorphosed hornblendic schists, two-thirds of a mile W S.W. of Lissan. This occurrence is referred to also in the Geological Survey memoir.†

Ballynahave. 1″ Sheet 34; 6″ Sheet Tyrone 45 S.W.

In this townland a branching vein of barytes, 4″ wide, tra-

* Geological Survey Memoir to Accompany Sheet 25 (1887), p. 20.
† Memoir to Accompany Sheet 27 (1881), p. 12.

verses the Old Red Sandstone conglomerate in a stream S.W. of Eshbane Hill.

Reclain and **Altaglushan.** 1″ Sheet 34; 6″ Sheet Tyrone 45 S.E.

Portlock, in his map,* indicates the occurrence of barytes in the stream at the boundary between these townlands. This record, however, was not confirmed by the officer of the Geological Survey who re-mapped the district about the year 1876. The only sparry mineral which he found in the locality effervesced with acid, and hence was not barytes.

Glenbeg. 1″ Sheet 34; 6″ Sheet Tyrone 45 S.E.

In this townland a vein of barytes, 4″ thick, appears in the Old Red Sandstone, close to the junction of this formation with the great felstone intrusion.

Findrum. 1″ Sheet 34; 6″ Sheet Tyrone 52 S.E.

Barytes occurs here in the Old Red Sandstone conglomerates, 1½ miles N.N.W. of the town of Ballygawley. The locality is given by Portlock,† and the exact site of the occurrence is indicated on his map.

Lislane. 1″ Sheet 45; 6″ Sheet Tyrone 58 S.W.

Traces of barytes have been found at Lislane, in the Old Red Sandstone conglomerates, immediately north of the Ballyness Dyke.

Cavanacark. 1″ Sheet 45; 6″ Sheet Tyrone 58 S.E.

A small E.–W. vein of barytes traverses the Old Red Sandstone conglomerates in this townland, a little to the south of the great Ballyness Dyke. Lislane and Cavanacark are presumably equivalent to the Clogher locality of Portlock.

Waterford.

The only mention of the occurrence of barytes in this county is that made by J. Hodgson Holdsworth in his paper "On the Geology of the District of the Knockmahon Mines, in the County of Waterford." ‡ According to this author the mineral occurs occasionally in the lodes at **Knockmahon** (1″ Sheet 178; 6″ Sheet Waterford 25 S.W.) in association with various copper ores, quartz, sulphuret of zinc, carbonate of iron, and argentiferous sulphuret of lead. The Knockmahon lodes traverse the Ordovician rocks and the associated felstones and ashes.

* Report on the Geology of the County of Londonderry, and of Parts of Tyrone and Fermanagh. Dublin, 1843.

† Ibid.

‡ Journ. Geol. Soc. Dub., vol. i. (1838), p. 85.

Westmeath.

Marlinstown. 1″ Sheet 99 ; 6″ Sheet Westmeath 19 S.E.

On the 6″ MS. Maps of the Geological Survey veins of barytes are recorded as occurring in the Lower Limestone beds exposed in the cutting of the Royal Canal, 2 miles S.E. of Mullingar.

Wexford.

Sir Robert Kane makes allusion * to the occurrence of several large veins of barytes on the seashore of Wexford. His reference is probably to the lodes in the Carboniferous Limestone found in the townlands of Killiane and Killiane Little, about 3½ miles S.S.E. of the town. These are included also in Kinahan's list of barytes deposits.

Killiane. 1″ Sheet 169 ; 6″ Sheet Wexford 43 S.W.

Two lodes, known as Sandford's † Lodes, outcrop in this townland, at the western margin of the South Intake. "They consist," according to the Survey memoir,‡ "of a 'north lode' N. 30° E., and the 'main lode' N. 45° E. The latter hades N.W. at from 50° to 80°, and in a trial shaft put down by Mr. Sandford in the intake, just inside the canal, it was found to be 5·5 feet wide. It 'principally consisted of hard brecciated ground in which were flying veins, and strings of baryte with specks of galena. At the south wall (foot wall) there is an eleven-inch rib of baryte, containing a half-inch vein of galena ;' but immediately S.W. of this trial in the canal, a rib of baryte with galena was also found at the hanging or north wall."

Killiane Little. 1″ Sheet 169 ; 6″ Sheet Wexford 43 S.W.

In Killiane Little, south of the site of the Sandford lodes, is another group of veins, known as the Felthouse Lodes. These consist of a main lode bearing N. 15° E. with two branches striking westward from it at N. 80° W. The weathered backs of the deposits are composed of disintegrated barytes and dolomitic sand. Galena was found in the main lode in the cutting for the canal.

Wicklow.

Brockagh and **Camaderry.** 1″ Sheet 130 ; 6″ Sheets Wicklow 17 S.W. & 23 N.W.

Barytes is sporadically distributed through the mass of the great Glendalough and Luganure lode, which cuts the granite

* Industrial Resources of Ireland (Second Edition, 1845), p. 245.
† The name is given as Stanford on the 6″ Survey Map.
‡ Memoir to Accompany Sheets 169, 170, 180, and 181 (1879), p. 52.

in the townlands of Brockagh and Camaderry. This lode, which has an average width of ten feet, bears due north, and extends northwards from the head of the Upper Lake, Glendalough, for a distance of over two miles. Galena is the principal ore, but it also contains zinc-blende, cerussite, small specks of copper ore, iron pyrites, and in places native silver. The gangue is chiefly quartz with calcite and barytes. The last, however, appears to form but a very subordinate part of the vein matter, and is probably of no economic value.

Baravore. 1″ Sheet 129; 6″ Sheet Wicklow 23 S.W.

In his Economic Geology of Ireland, Kinahan speaks * of a lode containing barytes, in quantity and of good quality, as occurring at Baravore, west of the Avonbeg. The reference is apparently to that known as the Baravore Lode, which is shown on the Survey maps; it appears in the granite, and bears N. 60° E. The lode also contains galena, zinc-blende, copper pyrites, and the black oxide and carbonate of copper. Kinahan states that it has only been partially explored.

Ballinafunshogue. 1″ Sheet 130; 6″ Sheet Wicklow 23 S.W.

In this townland a considerable lode, traversing the granite and schist, was formerly worked for lead and zinc ores. Kinahan† states that it also contained barytes, but he gives no particulars regarding the quantity or quality.

Clonkeen and **Corrasillagh.** 1″ Sheet 130; 6″ Sheet Wicklow 23 S.W.

A vein of quartz and barytes, with disseminated galena, zinc-blende, and other minerals, outcrops in the townland of Clonkeen. This lode traverses the granite near its junction with the mica-schist. A similar lode, which cuts both the granite and schist, occurs at the boundary between the townlands of Clonkeen and Corrasillagh. The former bears due east, and the latter N. 60° W. Referring to the lodes in these localities, Warrington W. Smyth states‡ that, in two of the three veins occurring in the south side of the Avonbeg valley, barytes appears "in ribs of sufficient width and purity to have been made the object of extraction."

* Journ. R. Geol. Soc. Ireland (1889), vol. viii., p. 120.
† Ibid, p. 120.
‡ "On the Mines of Wicklow and Wexford." Records of the School of Mines (1853), vol. i. part iii., p. 362.

CHAPTER V.

GENESIS OF BARYTES DEPOSITS.

In view of the comparative insolubility of barium sulphate the earlier writers were unwilling to accept the theory that deposits of barytes, such as form the infillings of great fissures and rock-cavities, could have originated by precipitation from solution. Some of these writers, having regard to the difficulties of presuming an aqueous origin for the mineral, put forward an alternative theory to account for the facts of its occurrence. According to this hypothesis barytes was forced up in the molten state into the rock-spaces of the upper lithosphere, in the same manner as molten igneous matter is squeezed into such fissures and rock-cavities to form the minor igneous intrusions. The arguments against this theory, however, are so convincing that it has ceased to be accepted by the geologists of the present day. As Hardman pointed out,* barytes is so infusible that the heat necessary to reduce it to a pasty consistence would be more than sufficient to melt the average rock. But no melting of the country rock, nor even any alteration of it that could be attributed to contact with molten barytes, has ever been observed in connection with the numerous known occurrences of the mineral. Furthermore, in many barytes lodes brecciated fragments of the rock-walls are of fairly frequent occurrence ; and while these are often completely immersed in the lode-matter, they never show any trace of fusion, as they most certainly should, had the barytes reached the fissure in the molten state.

On the other hand, such occurrences as the stalactitic barytes of Youlgrave, in Derbyshire, and the concretionary forms found at N.W. Spessart, and at other localities, would indicate that the mineral is of aqueous origin.

The structure of barytes lodes is very like that of other bodies of vein-minerals that are known to have been deposited from solution. In lodes of the aqueous type the infilling usually represents the material deposited from ascending thermal waters connected with some deep-seated magma. As these waters rise in the fissure, they lose, through relief of pressure and fall of temperature, some of their solvent powers ; and after the point of supersaturation is reached, they deposit their overburden on the rock-walls, filling the cavity by the growth of mineral matter in layers from the sides towards the centre. In many cases the mineral-bands thus deposited are more or less parallel to the walls of the fissure, and are symmetrical with respect to the middle line of the lode.

* Journ. R. Geol. Soc. Ireland, vol. v. (1880), p. 102.

A parallelism of this character has been observed in many barytes deposits. Bärtling* gives several instances of banded structure in the barytes lodes which he had an opportunity of examining in different parts of Germany. He found that the structure is rendered apparent in different ways. In some cases the successive layers are distinguishable by differences in the colour of the barytes ; in others by differences in the sizes of the component crystals ; and again, the layers are sometimes separated by the intercalation of thin bands of iron oxide or other material. But in whatever way the structure manifests itself, it indicates a distinct stratified growth of the vein-matter, which is clearly possible only through the medium of a solution occupying the fissure-cavity. The different bands record the changes in the rates, and in the conditions of precipitation.

Hence, in the process of its accumulation, barytes behaves quite similarly to many other vein-minerals. Nevertheless, the circumstances which govern its actual precipitation are very different from those that determine the separation of the latter. As already pointed out, the materials which go to form the ordinary vein-minerals arrive in the fissure in a state of solution, and are mechanically precipitated by the lowering of the solvent power of the magmatic waters in which they are carried. On the other hand, the formation of barytes is contingent on the intermingling in the fissure of two solutions, derived from different sources, and coming through different channels. It is now established that, whatever be the origin of its ingredients, barytes is formed by the interaction of a sulphate solution with one containing a soluble salt of barium, usually the chloride.†

The actual formation of the mineral in this manner may be seen taking place at the present day, in the coal mines of the neighbourhood of Newcastle-on-Tyne. The boxes and pipes of these mines become frequently choked with material of which barium sulphate forms the great bulk, roughly about 90 per cent. of the deposit. According to Professor Clowes‡ the material forms a loose non-crystalline powder with every indication of rapid precipitation. Barium Chloride is a common constituent of the mine-waters, and Professor Bedson has suggested§ that the precipitation might have been brought about by the chemical interaction of this salt with ferrous sulphate, or sulphuric acid, or both, since these substances are being constantly formed in the mines by the oxidation of the pyrites occurring in the beds associated with the coal.

* Die Schwerspatlagerstätten Deutschlands (1911).

† Breithaupt ingeniously suggested that the mineralisation of barytes lodes was brought about by the rise of barium sulphide in the fissures from a deep-seated source, and its subsequent oxidation to sulphate near the surface. ("Die Paragenesis der Mineralien," 1849, p. 204.)

‡ Proc. Royal Soc., vol. xlvi. (1889), p. 369.

§ Journ. Soc. Chem. Ind., vol. vi., p. 712.

Similar phenomena have been noted in the mines of the Rhine-Westphalian coal district, where barium sulphate is deposited in the mine-pipes to such an extent as seriously to interfere with the working of the pumps. Here the mineral springs contain only a relatively small amount of barium in solution ; yet when they mix with the sulphate-bearing mine-water, a considerable amount of barium sulphate is precipitated.*

Another striking case of the natural precipitation of barium sulphate has been studied by Lattermann in the Leopold Lode, near the town of Lautenthal, in the Harz. In the workings on this lode a mineral spring was encountered at a depth of 370 metres. Soon after it had been tapped, stalactitic deposits of barium sulphate began to appear in its neighbourhood, and incrustations of the same salt were formed in the mine-pipes.

A sample of the sediment gave the following analysis :

$BaSO_4$	94·3
$SrSO_4$	1·6
$CaSO_4$	·1
Fe_2O_3	·5
H_2O	3·6
	100·1

The waters issuing from the spring proved to be very rich in barium chloride ; so rich, indeed, that it has been estimated that they bring into the mine no less than 17·28 kilogrammes of the salt per day, or 6,570 kilogrammes (equivalent to 7,360 kilogrammes, or nearly $7\frac{1}{4}$ tons, of the sulphate) per annum. And in addition to the barium chloride, considerable quantities of the chlorides of calcium, magnesium, strontium, sodium, and potassium are introduced into the mine through the same medium.

Out of Lattermann's researches some important facts have come to light, which help us enormously towards the proper understanding of the genesis of barytes lodes. The most important of these relate to the part played by the associated chlorides in modifying the reaction between the barium chloride solution and the sulphates of the mine-water. He found that the chlorides by their presence retarded the velocity of the reaction between these solutions, while at the same time they materially increased the solubility of the barium sulphate produced in the process. A profound influence is thus brought to bear on the rate of precipitation of the salt, and hence on the physical character of the precipitate.

If we assume that the sulphates are in excess in the waters of a fissure, the continued ingress of soluble barium salts

* Beyschlag, Vogt, and Krusch : Ore Deposits (English Translation), Lond. (1916), vol. i., p. 137.

would lead to the gradual accumulation of barium sulphate ; and in time, after the supersaturation point of the salt had been exceeded, a slow precipitation of the material would take place. We have here a satisfactory explanation of the origin of the crystalline structure, which is the normal character of almost all barytes deposits. The presence of the chlorides which usually accompany barium salts in mineral springs, by retarding the rate of precipitation of the barium sulphate, ensures a sufficient time for crystalline growth ; and provided that suitable conditions of temperature are maintained, this makes possible the development of those large-sized crystals so frequently met with in many barytes lodes. Otherwise the separation of the salt would take place rapidly, and, as in the laboratory, the material would quickly settle in the amorphous, or micro-crystalline condition. The subsequent transformation of such an insoluble substance into the crystalline form would be difficult to understand, and, indeed, the persistence of the banded structure in many barytes lodes is evidence against any such re-arrangement of the material having taken place.

It now remains to inquire into the origin of the barium solutions which are concerned in the infilling of barytes lodes. This problem has received considerable attention from numerous workers who have studied the genesis of barytes deposits in other countries, particularly in Germany. In that country, the barytes lodes, in most cases, are found to be associated with the Zechstein and Bunter Sandstone series, or to occur in older rocks once covered by these formations. On account of this intimate connection it has been generally held that these Permo-Triassic rocks are the reservoirs from which the requisite supplies of barium are drawn to form bodies of barytes. It is true that a small amount of barium has been detected in the rocks of the Bunter Sandstone at several localities ; while Krusch, in his investigations into the fissure-springs of the coal district of Westphalia, found that the barium salts in these waters were confined to those parts of the area in which the Zechstein and Bunter Sandstone come in between the Chalk and the productive Coal Measures. But in spite of this weight of evidence the validity of the hypothesis is still open to question.

In the first place barium compounds do not appear to have been found disseminated in any of the Zechstein deposits, and where they have been obtained in the Bunter Sandstone they are, at least in some cases, of subsequent introduction. As an instance of the secondary character of these compounds, the occurrence of barytes crystals in druses of the Bunter Sandstone at Baden may be cited, and it is not improbable that barium always occurs in these sediments in the form of sulphate, whether disseminated as minute crystals, or as amorphous material. The formation of barytes in the interspaces

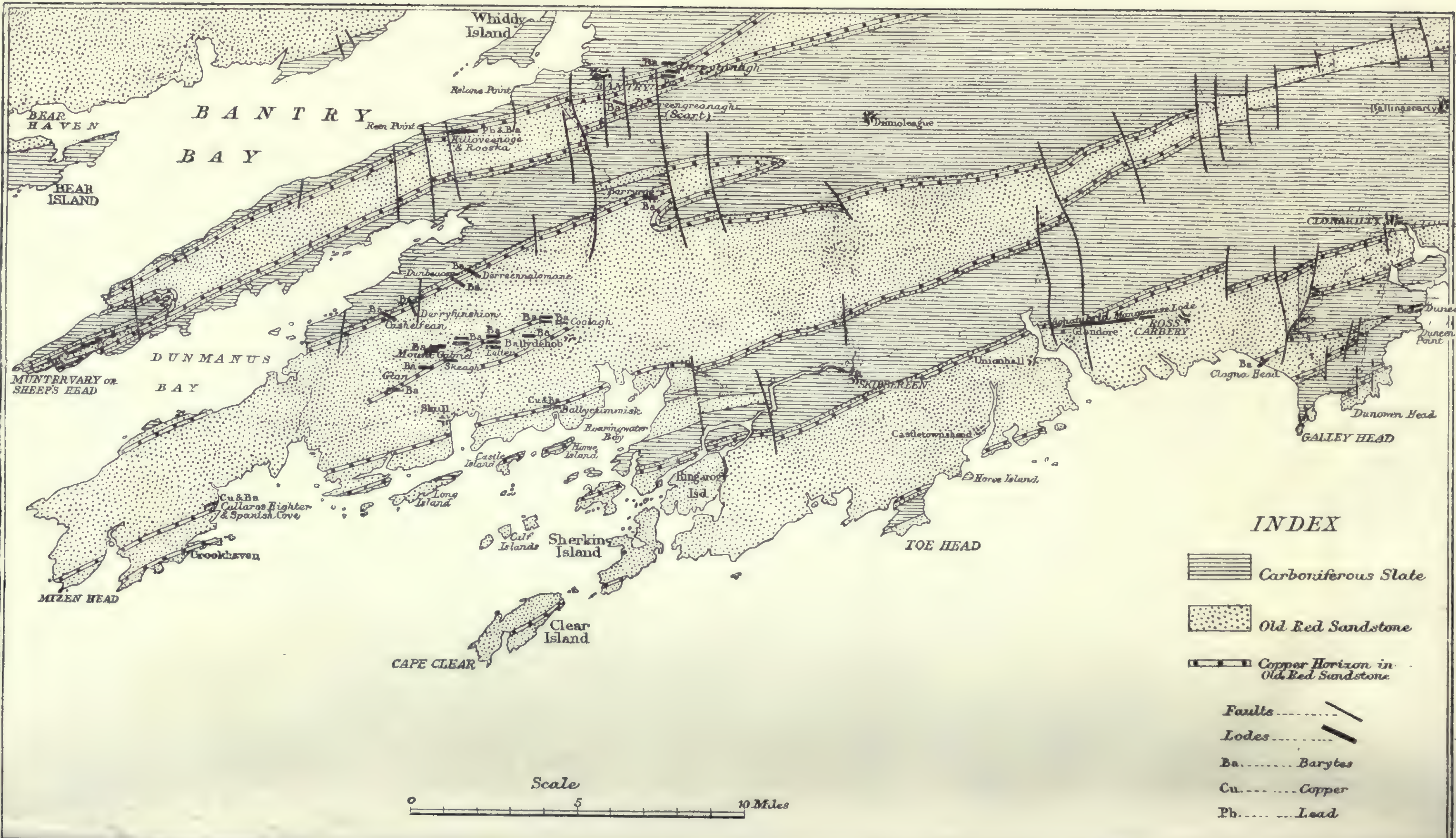
of the rocks might easily have resulted from the interaction of infiltrating barium solutions with the sulphates normally abundant in these deposits. If then, as is very probably the case, the barium of the Bunter Sandstone is present as the sulphate, it would be extremely difficult to remove it for concentration in the neighbouring fissures.

In the next place not all the barytes deposits of Germany show the same close connection with the Zechstein-Bunter Sandstone series, and a few of them, indeed, are generally considered to be older than these formations. Bärtling, who upholds the theory, admits that the introduction of barium into the Mommel Lode at Herges-Vogtei (in the Thuringian Forest) could be more easily explained on the assumption that the element arrived in the fissure from a magmatic source, issuing in the thermal springs that represented the last post-volcanic phase of the basaltic eruptions of the Thuringian Foreland.* Salomon is of the opinion that the formation of the barytes deposits by lateral secretion from the neighbouring rocks does not explain the great majority of the occurrences, especially those in the neighbourhood of the plain of the Rhine. He considers that the barium was derived from thermal waters reaching the fault-fissures from below, and adduces as evidence of the thermal activity in the margin of the Odenwald, such phenomena as the silicification of the Dossenheim porphyry, the bleaching of the Bunter Sandstone in Starckenburg and elsewhere, and the occurrence of zinc and lead deposits at Wiesloch-Nussloch.

But even if we assume with Bärtling and others that the great majority of the barytes lodes of Germany have been produced from the barium derived from the Zechstein-Bunter Sandstone series, a similar origin cannot be maintained for the barytes deposits of this country. Although the equivalent of the Bunter, and possibly of the Zechstein, is represented beneath the basaltic plateau of the N.E. of Ireland, and at its margin, with an outlier of the former farther south, in the Kingscourt area, we have no evidence to show that these deposits once covered the greater part of the country. The probability is that they were never deposited far outside the areas in which they are represented at the present day.

In view, therefore, of the non-existence of a Permo-Triassic cover, and of the absence of barium in the " country " of the lodes, we are forced to the conclusion that this element, in so far as it was concerned in the formation of the great barytes bodies, must have reached the fissures from a deep-seated source. When this is recognised, there is no further difficulty in accounting for the accumulation of the various barytes deposits which are found in all the older geological formations represented in Ireland. They have been produced

* Die Schwerspatslagerstätten Deutschlands. (1911), pp. 149–50.



BANTRY BAY
DUNMANUS BAY
BEAR HAVEN
BEAR ISLAND
Whiddy Island
Reen Point
Relane Point
BANTRY
Derreengreanagh (Scart)
Drimoleague
Ballinascarty
Pb & Ba
Killoveenoge & Rooska
Barryroe
CLONAKILTY
Derreennalomane
Derryfineshion
Cashelfean
Coolagh
Ballydehob
Letter
Mount Gabriel
Skeagh
Glan
MUNTERVARY OR SHEEP'S HEAD
Skull
Cu & Ba
Ballycummisk
Roaringwater Bay
Horse Island
Castle Island
Long Island
Cu & Ba
Callaros Eighter & Spanish Cove
Crookhaven
MIZEN HEAD
Calf Islands
Sherkin Island
Clear Island
CAPE CLEAR
Ringarogy Isd
SKIBBEREEN
Unionhall
Castletownshend
Horse Island
TOE HEAD
Glandore
ROSS CARBERY
Clogna Head
Duneen
Duneen Point
Dunowen Head
GALLEY HEAD
INDEX
Carboniferous Slate
Old Red Sandstone
Copper Horizon in Old Red Sandstone
Faults
Lodes
Ba. Barytes
Cu. Copper
Pb. Lead
Scale
0
5
10 Miles

in the manner already described. When a solution of barium chloride, or other soluble salt of barium, reaches the upper portions of a fissure, and comes in contact with a solution of the sulphates produced from the metallic sulphides in the zone of oxidation, a chemical reaction takes place, whereupon barium sulphate is produced, and is gradually deposited on the walls of the fissure. The body of barytes is thus formed in place by the chemical interaction of an ascending solution with a descending one, and its limitation in the lode to the superficial zone is fully explained by its peculiar mode of origin.

The dependence of the formation of barytes lodes on the sulphides in the rocks of the superficial zone is well illustrated by the distribution of barytes in the south of Ireland. A glance at the accompanying map (Plate II) is sufficient to show that, in the Old Red Sandstone district of Cork, the barytes deposits are strictly confined to a definite horizon, in fact, to a narrow belt towards the top of the series.

On the basis of lithological differences in the strata an attempt has been made by the Geological Survey to divide the Old Red Sandstone of the district into an Upper and Lower series, and although the boundary between the series does not correspond with that adopted in Scotland, it seems to mark a definite stratigraphical horizon. Through a thickness of about 300 or 400 feet, near the base of the Upper series, the beds are impregnated with copper ores, chiefly copper pyrites, bornite, and their oxidation products, and this copper-bearing belt persists throughout the whole of the south of Ireland, extending from Waterford to Kerry. All the barytes lodes of the formation cut the copper belt, and although here several fissures of the same system, and presumably of the same age, traverse other horizons of the Old Red Sandstone, none of them carry barytes, but are infilled chiefly with quartz associated with small quantities of micaceous iron. It is also interesting to note that when the lodes cross the horizon, barytes gives place to quartz soon beyond the limits of the copper belt. The obvious inference from this distribution of the mineral is that the copper beds are concerned in its formation, the ores, by their oxidation, furnishing the precipitant for the barium salts arriving in solution through the fault-fissures.

As already mentioned, the very process by which barytes is produced determines its limitation in depth in the neighbourhood of the oxidation zone. Other explanations of the phenomenon have been offered. For example, the failure in depth has been ascribed to the greater solubility of the mineral, due to the increased temperature and pressure or to the accumulation of chlorides in the deeper parts of the fissure. But such explanations seem to be unnecessary. The failure of barytes, both laterally and in depth, is sufficiently accounted for by

the necessarily limited range of movement of the sulphate waters in their conducting channels.

As will be seen from the map (Plate II.), the other barytes lodes of the Cork district, as at Bantry and Clonakilty, occur outside the Old Red Sandstone formation, and are, of course, unconnected with the copper horizon of the series. For these, however, the necessary sulphates appear to have been supplied by the oxidation products of the local pyrites deposits, or of other sulphide minerals, the barium being magmatic as before.

In most of the other districts in Ireland barytes occurs as the gangue of sulphide ores. The paragenesis in these cases would indicate that it was the latest introduction in the process of the infilling of the fissures, arriving long after the metallic minerals had been deposited, and depending upon the partial oxidation of these for its precipitation. For the addition of barytes to the lodes it would seem as if a re-opening of the fissures were necessary. Such a re-opening might easily have taken place during the late Mesozoic or early Tertiary earth-movements, when, as will be seen from the next chapter, the accumulation of our barytes deposits is most likely to have taken place.

A somewhat different and more complex origin must be ascribed to the barytes bodies in the Lower Carboniferous series of the Silvermines district, Co. Tipperary. As already stated in the preceding chapter, the mineral occurs here interbedded with compact dolomitic limestone, or it appears in association with calamine (smithsonite of Dana), hemimorphite, galena, and other mineral in the great gossan, which is an altered limestone bed near the base of the series. These occurrences bear no analogy to the deposits of the true fissure lodes, and cannot be regarded as ordinary cavity-fillings. Neither, on the other hand, are they detrital sediments, although they extend in sheets more or less concordant with the general bedding. They are, in fact, younger than the superincumbent strata, and have been formed by replacement of the original rock, on the introduction of mineral matter through the medium of infiltrating solutions. This alteration of the rock, however, was not accomplished by direct metasomatic replacement, whereby the limestone was slowly dissolved away, and barytes exchanged for it, molecule by molecule. The process of substitution took place in successive stages. Following upon the Hercynian folding, solutions of several sulphide ores were introduced into the fault fissure that forms the boundary between the Carboniferous Limestone and the older Palaeozoic formations, and these mineralising solutions found their way into the limestone beds through pre-existing cracks, but mainly along the bedding planes of the strata. In their progress they gradually dissolved away the limestone rock, and substituted the sulphide ores, chiefly galena, zinc-blende, and iron pyrites, by the process

of metasomatic replacement. During subsequent earth-movements, barium solutions invaded the rocks through the same channel, probably on a re-opening of the fissure, and these, on coming into contact with the oxidation products of the sulphide ores, formed barytes by double decomposition. The replacement of a sulphide deposit by this mineral is by no means unique; it is known to have taken place on a gigantic scale in the great deposit of Meggen, in Westphalia,* where a bed of iron pyrites has in part been replaced by barytes.

CHAPTER VI.

AGE OF THE BARYTES DEPOSITS.

Barytes Deposits of the South of Ireland.

Before discussing the age of the barytes deposits of the South of Ireland, it is desirable to consider briefly the geological structure and the topographical features of the country in which they occur.

The solid rocks represented in the district belong to the Palaeozoic group, and if we except as of doubtful age the deposits of the Dingle promontory (with which, however, we are not here directly concerned), all of them are included under the Old Red Sandstone and Carboniferous systems.

In this area the Old Red Sandstone attains great development; it is represented by an immense thickness of arenaceous and clayey sediments of continental facies, forming the great masses of conglomerates, and green and purple grits and slates which are largely responsible for the grandeur of the mountain scenery of the South of Ireland. At the top of the typical Old Red Sandstone and strictly conformable to the underlying strata is a small series of sediments, known as the Yellow Sandstone or Kiltorcan Beds, or in older times as the Upper Old Red Sandstone of Ireland. In a few localities these beds are lithologically distinguishable from the rocks below, but generally, in the absence of fossil evidence, they can only with difficulty be separated from them in the field. From the present standpoint the Yellow Sandstone series is of special interest, since in intimate relation with it stand most of the barytes lodes of West Cork.

After the Yellow Sandstone had been laid down, there took place a gradual subsidence of the area, which admitted the sea over the Devonian land, and then there followed without a break the deposition of the whole of the Carboniferous sequence. In the extreme south, however, the lower beds of the

* Bärtling, "Die Schwerspatslagerstätten Deutschlands" (1911), p. 26, *et seq.*

Carboniferous are of a distinctive facies. North of the latitude of Cork only a small thickness of shales interposes between the Carboniferous Limestone and the Old Red Sandstone; but south of this line a remarkable group of dark argillaceous sediments, and of arenaceous beds interstratified with clayey bands, comes in above the latter formation. These deposits, which are known as the Carboniferous Slate and Coomhola Grits series, gradually swell out towards the south-west, attaining a thickness of more than 8,000 feet at the shores of Bantry Bay; they are the equivalent of the Lower Limestone Shale, and possibly of part of the Lower Limestone, as developed farther north.

Towards the close of Carboniferous times a period of great crustal disturbance set in, during which the western and central parts of the European area were affected, a wide zone, extending from the S.W. of Ireland, through South Wales and the south of England, into Belgium, Brittany, and central Europe generally, being involved. Along this belt intense folding took place, and there were raised a series of formidable mountain ridges, probably of Alpine proportions, known as the Armorican or Hercynian Chain. The ridges have now been worn down, however, to a comparatively low relief, and the residual stumps have in many places been buried beneath newer deposits.

Lying well within the zone of the Armorican movements, the Cork and Kerry areas were involved in the folding. The country was wrinkled into troughs and ridges, which in the west have a W.S.W. to E.N.E. trend, but which curve round towards the east as the Waterford coast is approached. Originally deposited in a more or less horizontal position, the beds were thus bent into a series of great anticlines and synclines. While the folding was in progress, the area affected slowly emerged from the sea. The rising land, now exposed to the action of the subaerial denuding agents, was gradually worn away, and in time the surface became degraded to a gently sloping plane of low relief, forming, in fact, part of the ancient peneplain of the British area, known as the Palaeozoic Floor.

In the periods immediately following upon this peneplanation, little is known of the history of the Irish area. But it is almost certain that it was drowned in the great transgression of the sea which began in Albian times and reached its maximum in the Lower Senonian; and that, during this submergence, strata representative of the Cenomanian to Senonian were deposited. Towards the close of Cretaceous times the land again emerged from the sea, and during the cycle of erosion thus inaugurated, the soft Mesozoic sediments were completely worn away. The laying bare of the Old Red Sandstone anticlines was brought to completion, and the weaker Carboniferous rocks were in part eroded from the synclinal troughs. Thus, by the progress of differential weathering, the hard Old Red Sandstone cores were

left to stand out as prominent east and west ridges, separated by parallel valleys carved out of the less resistant Carboniferous rocks of the synclines. In all this area only in a few exceptional cases do the Carboniferous deposits occupy high ground.

A point of some importance for the study of the relations of the lodes that traverse the belt to the enclosing rocks is the secondary structure set up in the latter during the Armorican movements. In the process of folding a distinct cleavage was developed, which now forms the most conspicuous feature of the deposits, the original bedding, except in certain localities, and in the case of the coarser-grained sediments, being for the most part obscured. The planes of cleavage run in the direction of the strike; they are nearly vertical, and cut the bedding at various angles, according to the parts of the folds that they intersect.

Numerous fissures, infilled with various minerals, traverse the Armorican belt in the south of the counties of Cork and Kerry, but with the exception of a few in the Carboniferous Slate, and of those that appear in the Yellow Sandstone series, they carry quartz alone, or quartz associated with small quantities of micaceous iron. In the Yellow Sandstone, on the other hand, many of them are infilled with barytes, copper ores, or in the case of the great Aghatubrid Lode, manganese ores, as the principal minerals. Most of the lodes run east and west, intersecting the cleavage at a low angle, but a few, such as those of Dereennalomane and Caherolickane, as well as some of the Allihies copper lodes, traverse the belt in other directions. All, however, strike across the Armorican structure of the country, and are clearly of post-Armorican date.

The so-called "copper-lodes" that follow the strike must be distinguished from the true copper lodes that occupy fissures. The former are in reality mineralised beds, which, according to Jukes,* received their copper as detritus from the pre-existing lodes of an adjoining land, as the beds were being deposited. On his showing, therefore, the mineral matter of the "lodes" would be contemporaneous with the rocks themselves. That, on the other hand, the beds might have become mineralised by metasomatic replacement after deposition is a possibility which is by no means excluded. But in either case it is certain that the bedded copper deposits are older than the true lodes of the district, since they are always cut by the latter.

To what date, then, subsequent to the Armorican folding, are the fissuring and infilling of the fissures with barytes to be ascribed? From the stratigraphical evidence alone it is impossible to determine, since, with the exception of the Glacial drifts, there have been preserved in the area no sediments newer than the Carboniferous to serve as a time-

* Geol Sur. Memoir to Accompany Sheets 200, 203–5, 199 (1861), p. 27.

reference. Accordingly, if we are to find a satisfactory answer to the question, we must look for it in another direction.

We have already seen that barytes is a mineral that originates near the surface of the earth's crust, one of the essential re-agents concerned in its formation being a product of the oxidation zone. And since, in consequence of the insolubility of the mineral, its subsequent migration is highly improbable, the barytes deposits which we find in the rock-fissures must have been deposited in relation to a land-surface, that is to a surface where atmospheric oxygen was at hand, and (as we shall presently see) to one well advanced towards the ultimate stage of the erosion cycle.

Peneplanation, in fact, would appear to be a necessary preliminary to the production of barytes lodes. In a mature land-surface worn down to low relief, the ground water attains to a condition of stagnation, or at least to one of sluggish movement, and under such conditions alone are the chemical reactions necessary for the production and deposition of barytes, in a sheet of any great vertical depth, to be expected.

If, on the other hand, the land-surface were elevated and deeply trenched with valley cuts, the ground-water, descending in a steep gradient, would flow off with comparative rapidity into the streams, and carry with it the decomposition products of the oxidation zone as fast as they were formed. The diffusion of the soluble sulphates to depth, and their intermixture and reaction with the magmatic barium solutions rising through the fissures would, under these circumstances, be unlikely to take place.

This connection between the barytes lodes and an old land-surface has actually been observed in certain parts of Germany. In the old plateau of Spessart, situated in the N.W. of Bavaria, and again, in the Clausthal district of the Harz, the barytes lodes are found only in the highest ground, and are completely absent from the floors of the valleys excavated by the present streams. The obvious inference is that, as contended by Bärtling and others, they must have been deposited in the rock-fissures of the plateau before it became trenched and dissected by the modern rivers.

It now remains for us to inquire whether we can get any clue as to the date of the development in the Irish area of the land-surface to which the barytes lodes are related. That this land-surface is not identical with the Palaeozoic Floor is a conclusion to which we are forced by the consideration of the vast amount of material that must have been worn away from the land since the peneplanation that followed upon the post-Carboniferous uplift. It has been shown by Professor Hull* that, in the neighbourhood of Dublin, at least 2,490 feet of strata have been denuded away since the Coal

* "On the Origin of 'The Scalp.'" Proc. R. Dub. Soc., vol. i. (1878), p. 13.

Measures were laid down, and probably the same is approximately true of the rest of the country. Much of this erosion, of course, took place during the actual peneplanation of the Palaeozoic Floor. But, making due allowance for this, it is reasonable to suppose that a depth of strata, greater than that to which barytes lodes could extend from the surface, must have been removed in the degradation of the land during the subsequent long drawn-out periods of elevation. If, therefore, the barytes lodes had been formed in relation to this peneplain, they, too, would have been denuded, and all traces of them would have disappeared from the Irish area.

The assumption of a peneplain of much more recent date, therefore, becomes a necessity, if we are to explain the facts of the barytes occurrences as we see them in Ireland.

Unfortunately there is but little evidence to enable us to determine the geological period at which this peneplain was developed in the Irish area, and it is in the first instance necessary to turn for light to Central Europe, where the geological record is more complete, and the evidence for the later disturbances more obvious.

In the region of Thuringia and the Harz, Philippi* has shown that the country was subjected certainly to one, but probably to many, dislocations between the epochs of the Armorican and Middle Tertiary upheavals; that these movements exceeded that of the Middle Tertiary in intensity; and that many of the disturbances which had hitherto been referred to the Middle Tertiary must now be regarded as having occurred at a much earlier date. He has further shown that the Mesozoic and early Tertiary dislocations were each followed by a long period of denudation, during which the uptilted rocks of different geological ages were planed down to a general level, forming a peneplain recognisable over a wide area; but that, while much of the Mesozoic cover was removed by the agents of erosion, very little of the pre-Permian land-surface was laid bare. Where the ancient schists come to light, their present more or less even surface is seen to have no relation to the old Palaeozoic Floor, and the levelling must, therefore, be regarded as due to a later peneplanation. Beds of Oligocene age were subsequently deposited upon this eroded surface, and in places, as in Hahnberg, these in turn were capped by the Cainozoic Basalt. Naturally, the peneplain is well preserved only where it is still covered with the remnants of the Oligocene or later deposits. In many places its plateau-like character has been largely obliterated by the Middle Cainozoic dislocations, and the terrain has been further remodelled by the development of the river-systems from the Oligocene period onwards.

In this region the principal movements between the

* "Über die präoligocäne Landoberfläche in Thüringen." Zeitschrift der Deutschen Geologischen Gesellschaft, Bd. lxii, (1910), p. 305 et seq.

Armorican and Middle Cainozoic tectonic epochs took place after the Upper Jurassic, and before the Oligocene period. One of them appears to have preceded the Chalk, and this was followed by another considerable disturbance in Senonian or early Tertiary times. Outside the area here considered, the movements have left their impress upon the structure of the country south of the Thuringian Forest, and, as shown by the investigations of H. Stille, O. Grupe, and others, they have also affected the district of N.W. Germany. It will be seen, therefore, that these were not mere local phenomena, but upheavals of regional proportions.

Turning now to Ireland, we find in the southern and south-eastern counties the relics of a well-marked peneplain, obviously newer than that which completed the cycle of erosion following upon the Armorican uplift. This old land-surface has been recognised by many observers, though no description of it appears to have found its way into geological literature ; * it may be seen at many places inland, lying at an elevation of about 600 to 800 feet above the present sea-level, sloping, however, in every direction towards the coast. The barytes lodes were in all probability developed in relation to this ancient land, though it must be confessed that the direct evidence connecting the lodes with the land-surface is but slender. Not inconsistent with the hypothesis, however, are the elevations above sea-level of the outcrops of the principal deposits of the south of Ireland, which are approximately as follows : Derryginagh, 400 feet ; Scart, 563 feet ; Dereennalomane, 360–390 feet ; Mount Gabriel, 450-890 feet ; Glan, 300 feet ; Letter, 300-500 feet ; Cashelfean, 800 feet ; Duneen Mountain, 300 feet ; Coolagh (near the coast), 100 feet ; and Duneen Bay (at the coast), 100 feet. It has been found, moreover, that, even where most favourably situated with respect to the copper horizon, the lodes when followed into the lower ground show that the barytes is failing, as if the roots of the lodes were being laid bare.

In consequence of the complete absence of the Mesozoic and Cainozoic deposits from the southern area no definite conclusion regarding the age of the peneplain can be reached, on the basis of the local stratigraphical evidence. But passing to the north-east of Ireland, we find a more complete record. Here, beneath the Tertiary basalt of the Antrim plateau, the Mesozoic sediments have been preserved from denudation, and we are enabled to catch a glimpse of the physiographical conditions that obtained in this region during the long interval from the Armorican uplift to the outpouring of the basaltic lavas. Reviewing the stratigraphy of these deposits, we find

* Prof. Cole refers to this peneplain in his description of the Raised Map of Ireland (General Guide to the Nat. History Collections, Nat. Mus. Dublin), 2nd ed. (1920), and reproduces (p. 9) from the Geological Survey Memoir to accompany Sheets 176 and 177, a drawing which admirably illustrates the feature as developed in the Knockmealdown Range.

in the first place a very incomplete representation of the Jurassic System. All the beds higher than the Lower Lias are wanting, the Chalk resting upon the denuded surface of this series. There is thus indicated in this area a prolonged period of elevation of the land prior to the deposition of the Chalk, and this, as we have seen, has its counterpart in Central Europe, where, in the Thuringian district, a similar elevation, followed by prolonged denudation, took place in late Jurassic times.

The next episode in the history of the area was the sinking of the land and the return of marine conditions. During this submergence sediments representative of the Cretaceous System (Cenomanian to Senonian) were deposited. But subsequent to this, and prior to the eruption of the Tertiary lavas, the area was again uplifted, and a new cycle of erosion inaugurated. Such beds as had been deposited above the Chalk were denuded, and the Chalk itself was worn down to a mere sheet of about 100 feet thick or less, its surface being left covered with a residual soil, composed mainly of flints. Since the Lower Basalt that was erupted over this surface maintains a remarkable uniformity of thickness throughout, the presumption is that the lava must have flowed over comparatively level ground. A late stage in the cycle of subaerial erosion had, in fact, been reached, and the land had been degraded to the nearly uniform level of a peneplain.

This peneplain has naturally been involved in the Tertiary (Cainozoic) earth-movements, from which it suffered considerable dislocation. During the recent investigations of the district by the Officers of the Geological Survey, W. B. Wright was able to detect minor interbasaltic disturbances of the plateau in the vicinity of the Giant's Causeway, while subsequent dislocations on a far larger scale, involving the Upper Basalt, are visible in many places. If now we assign to the extrusion of the basalt an Eocene, or perhaps Oligocene, date, the age of the peneplain of the Antrim plateau must be regarded as late Cretaceous or early Tertiary. We have here, accordingly, the counterpart of the pre-Oligocene land-surface of Thuringia, described by Philippi, to which at least many of the barytes lodes of that district are related.

It is here suggested, though of course it cannot be established with certainty, that the peneplain so well marked in the mountain districts of the south and south-east of Ireland forms part of that preserved beneath the basalt of the Antrim plateau. This assumption may at first sight seem unjustifiable, but it will not appear so far-fetched when we consider the alternative. While it is true that many epochs of uplift and denudation are indicated by the surfaces of erosion visible in the British rocks of different ages,* most of these have

* See C. B. Travis, "Some Evidence of Peneplanation in the British Isles," Presidential Address, Proc. Liv. Geol. Soc. (1914), part 1, vol. xii., p. 3.

obviously no bearing on the present problem, and need not be considered here. The great periods of erosion of the Mesozoic and Cainozoic eras are all that need concern us. If then the peneplain beneath the basalt of the Antrim plateau and that of the South of Ireland be not coeval, the latter must have been produced either in post-Basaltic times, or in the period immediately following upon the late Jurassic uplift. Neither of these possible dates, however, would appear upon closer examination to meet the case. For, in the first place, in view of the enormous extent to which the country has been remodelled since the peneplain was formed, it is difficult to assign its origin to a period so comparatively modern as that succeeding the outpouring of the Antrim basalt. And although in the interval the denudation of the British area has been considerable, as evidenced, for example, by the clearly post-Basaltic excavation of the Lomond Glen,* yet the time available would be insufficient to allow for the formation of the peneplain, and for its almost total subsequent destruction. Again, while we have evidence of a, perhaps, complete emergence of the land in the British area towards the close of the Jurassic period, there is nothing to show that a mature stage of the physiographical cycle had been reached before the transgression of the Cretaceous sea.

On the other hand, an early post-Cretaceous date for the peneplain of the South of Ireland may be inferred from analogy with a similar feature in Great Britain. The counterpart of this old land-surface has been clearly recognised in the Central Uplands of Wales.† Here the geographical cycle opened, it is believed, upon a surface of Upper Cretaceous rocks, on the slope of which the present river-system originated. Again, from the consideration of the development of the river-system of South Wales, Strahan‡ concludes that the existing streams of that district also must have been initiated upon the surface of a similar cover, since they have maintained their courses independently of the structure imposed by the Armorican and Charnian movements. In support of this contention he cites the parallel case of the Dorset area, in which the folded Jurassic rocks form the substratum of the Upper Cretaceous. In this district the rivers occupy valleys which have no connection with the Jurassic structure. Similarly, it is reasonable to suppose that the older formations of the Irish area were likewise blanketed over with Cretaceous rocks, and that the peneplain we have been considering was produced by the degradation, close down to the base-level, of the land-mass of which these deposits formed a part. The surface of erosion

* H. J. Mackinder, " Britain and the British Seas," Lond. (1902), p. 133.

† W. G. Fernsides, " Geology in the Field " (Geol. Assoc. Jubilee Vol., 1910), p. 788.

‡ A. Strahan " On the Origin of the River-System of South Wales " Quart. Journ. Geol. Soc. (1902) vol., lviii. p. 219.

would trench equally across the older and the newer sediments, and upon the subsequent elevation of the land, as a result o the Middle Cainozoic earth-movements, the softer Cretaceous deposits would be denuded away, and the Palaeozoic rocks again brought to light. On this hypothesis the peneplanation of the South of Ireland would correspond in date with the erosion of the Antrim Chalk, and the old land-surfaces of these areas would in all probability represent the mature stage in the base levelling of the same post-Chalk plateau.

We have already assumed that the barytes lodes of the South of Ireland stand in intimate relation with this peneplain. If this assumption is justifiable, then we must regard them as having been formed probably in late Cretaceous or early Tertiary times.

Age of the Barytes Lodes of the Sligo District.

In the Sligo district the barytes lodes of Gleniff and King's Mountain traverse the Upper Carboniferous Limestone, and are, therefore, newer than this series.

The ground in which they lie rises, in the table-land of Benbulben and the adjoining mountains, to a fairly uniform height above the general level of the Central Plain, and furnishes one of the few instances in the Irish area in which the Limestone series reaches to any considerable elevation. The plateau is deeply trenched by the present streams, forming valleys excavated in the limestone beds, in some cases to a depth of more than 1,600 feet. The topography is suggestive of portion of an ancient peneplain, partly obliterated, indeed, through the long-continued weathering of the soluble limestone, and further incised and remodelled by the obviously modern river-system.

In consequence of the geological structure of the country, however, the characters which usually serve as criteria for the recognition of this type of land-form are not here discernable. The strata are nearly horizontal, and there is little or no diversity in the rocks that appear at the surface, as we traverse the plateau. Hence we are unable to say with confidence that the land-surface is of subaerial origin. On the other hand, it is significant that, as at Spessart, at Clausthal, and in the South of Ireland, the lodes are well developed only on the hills, and do not appear to descend into the deep valleys. The barytes had consequently been deposited before the valleys were excavated and, as we infer from theoretical considerations, after the plateau had reached a mature stage in the erosion cycle. Although it is not possible to produce evidence that would establish the connection between this old land-surface and that of the North-east, and of the South of Ireland, the presumption is that they formed parts of one and the

same peneplain; and from this it would follow that the barytes lodes of the Cork and Sligo districts are of contemporaneous origin, and were formed some time between the period of erosion of the Upper Chalk and the outpouring of the Tertiary lavas.

Age of the Remaining Barytes Deposits.

The remaining Irish barytes deposits occur in association with metallic ores, mainly lead and zinc, in the fissure-lodes of the older Palaeozoic formations. As examples of this type the silver-lead-barytes deposits of Silvermines, Co. Tipperary, of Glendalough, Co. Wicklow, and the lodes of Monaghan, Armagh, and Down, may be cited. The bedded barytes deposits occurring in the Lower Carboniferous Limestone, at Silvermines, are also referable to this group.

Finlayson* associates the formation of the ore deposits of the British Isles with the four great epochs of disturbance and vulcanicity, viz., the Huronian, Caledonian, Hercynian, and early Tertiary; and he ascribes to the Hercynian period the copper, lead, zinc, and barytes fissure-lodes of the older geological formations, that show a community of type. The arguments in favour of this generalisation are, however, inconclusive. The lead deposits of Glendalough, for example, have no relation to the Hercynian structure, and are much more likely to be connected with the intrusion of the Caledonian granite of the Leinster Chain. As we have already seen, the barytes lodes of the South of Ireland are certainly much later than the Armorican folding. It is possible, however, that the fissuring might have taken place on the settling of the crust soon after the area had been relieved from the orogenic stresses that produced the folding, but in any case the infilling of the fissures with barytes must be referred to a later geological period.

In this connection the manner of the infilling of the lodes of the Harz district is of special significance. The fissuring in this area, according to Klockmann, took place not long after the Hercynian folding. On the other hand, it is apparent from the structure of the lodes that the various ores and gangue minerals were not deposited simultaneously, but that the infilling of the fissures was a prolonged process, involving the re-opening of the rifts, and the gradual introduction of successive generations of minerals. The lodes are ore-bearing only in the old mountain core of the Oberharz, while, in the Zechstein foreground of its southern and western rims, the lodes occupying fissures of the same system consist mostly of barytes alone. From this fact it is reasonable to suppose

* "The Metallogeny of the British Isles." 'Quart. Journ. Geol. Soc. vol. lxv., pp. 281 et seq.

that the fissures of the mountain core had been produced and infilled with ores, before the Permian Zechstein was deposited. From his examination of the district, Klockmann concludes that the metalliferous lodes are considerably older than the Zechstein, the fissures which they occupy having first appeared in late Carboniferous, or early Permian times. The lodes traversing the Zechstein-Trias cover, on the other hand, have in many cases been proved to be related to the pre-Oligocene peneplain, and are therefore of late Mesozoic, or of early Cainozoic date. The rim faulting in which the Zechstein was involved was probably due to a revival of the old fissuring processes, whereupon the rifts were re-opened, and new types of mineralising solutions were introduced, the most prominent amongst them being solutions of barium. Thus, whether it occurs as a gangue mineral, or as a principal mineral, all the indications go to show that barytes is one of the youngest constitutents of the deposits.

As Finlayson points out, the fissuring of the rocks and the infilling of the fissures with metallic ores have undoubtedly been associated in the British area with the earlier epochs of great crustal disturbances. In Ireland, at least, the formation of the metalliferous lodes was connected mostly, if not entirely, with the Caledonian and Hercynian earth-movements, and with the intrusion of the granitic masses that accompanied the former. This, however, is not true of the barytes deposits. In the Harz district, even when it is associated with metallic ores of undoubted antiquity, barytes has been shown to be of subsequent introduction, having been deposited on the re-opening of the fissures probably during the late Mesozoic or early Cainozoic earth-movements. Reasoning from analogy, we may presume that such of our metalliferous lodes as contain barytes have had a similar history. The fissures which they occupy were conceivably torn open again during the late Cretaceous or early Tertiary disturbances, and the barytes was deposited in them with respect to the post-Chalk peneplain.

We thus conclude that all the Irish barytes deposits were contemporaneous in their origin, having been accumulated towards the close of the Mesozoic or at the beginning of the Cainozoic era; that they were formed in the superficial parts of the fissures which opened on an old peneplain of post-Senonian and pre-Basaltic age; and that they occupy either new rifts in the crust produced during the later earth-movements, or pre-existing ones, re-opened by a late revival of the old fissuring processes connected with the Caledonian and Hercynian foldings.

The basis upon which these deductions are founded is admittedly slender. Yet, from the geological evidence, such as it is, as well as from analogy with the majority of the barytes lodes of Central Europe, the generalisation here reached would appear to have a reasonable amount of justification.

CHAPTER VII.

INDUSTRIAL USES OF BARYTES.

Barytes was originally used mainly as an adulterant for more valuable commodities, such as white lead, putty, sugar, etc., its physical and chemical characters, as well as its cheapness, rendering it eminently suitable for the purpose. Hence it came to be looked upon with suspicion from the very beginning of its industrial employment, and its doubtful reputation has pursued it even to the present day. Most of its more modern applications, however, are of quite an orthodox character, and its legitimate uses are becoming progressively more and more extensive and important.

Probably by far the greater bulk of the barytes now put upon the market is absorbed by the paint industry, to be employed either as a white paint, or to serve as a basis for coloured pigments. For general use in the former capacity, the grinding of the mineral to a fine powder is usually all the preparation that is necessary ; and in the ground form it furnishes one of the most valuable and widely used of the white paints, ranking next to white lead in importance. One of its greatest advantages lies in its cheapness ; but apart from this, it is valuable for its permanence, being unaffected by the weather, or by sulphuretted gases, which so seriously discolour white lead. Furthermore, it forms an excellent blend with other white paints, giving to these substances " tooth " or adhesiveness, as well as bulk.

For higher class work the precipitated barium sulphate or " blanc fixe " is preferred to the natural product. Under various trade names, such as " Constant White," " Permanent White," etc., " blanc fixe " is extensively used as an artists' colour ; it furnishes a pure white pigment of great permanence and opacity.

Fineness of division and whiteness of colour are the qualities which determine the commercial value of the milled product intended for use as a paint. Barytes is usually graded according to colour, and this is judged in a very simple manner. If a small quantity of the ground mineral is transferred to a glass plate, then flattened into a thin cake with a knife or a spatula, and moistened with a few drops of oil of turpentine, the discoloration due to any impurities, such as iron, is brought into prominence, and the grade of the sample can be judged from the extent of this discoloration. By means of the following modification of the test it is possible to discriminate between samples which approximate to each other so closely in grade that no difference is apparent when judged in the ordinary way : If, say, small quantities from each of

two samples are placed in contact on the glass plate so that they are separated by a sharp line of junction, and then flattened and moistened as before, any differences in grade will be apparent on contrasting the colours of the treated cake on the opposite sides of the line of junction.

The various impurities that prejudice the quality of barytes are injurious, not only according to the quantity of these substances in a deposit, but also according to their mode of distribution through its mass. Common associates of barytes, like zinc and copper ores, for example, occur in nests or aggregates, and can be removed during or after the extraction of the mineral from the mine. Galena, on the other hand, frequently appears in the form of disseminated crystals that cannot be eliminated by any practical method, and hence it constitutes a very objectionable impurity. One part of galena in 10,000 will impart a permanent grey colour to the milled product, and render it unsuitable for use as a white paint. Again, iron oxides, which are perhaps the commonest impurities of all, do not often admit of mechanical removal. They penetrate into the cracks and cleavages of the mineral, and yield only to bleaching, i.e., treatment with dilute sulphuric acid. A slight discolouration due to iron is, however, not a serious drawback, since it can be easily masked by milling the barytes with a small quantity of ultramarine.

Barytes mixes easily with organic colouring matter, and thus serves as a basis for many coloured pigments, enabling small quantities of these materials to be spread over large surfaces.

Barytes is of considerable importance in the chemical industry for the production of various chemical reagents, such as barium chloride, barium hydroxide, etc. One of its derivatives is largely used in the commercial production of oxygen, by Brin's process; and another, barium dioxide, for the preparation of hydrogen peroxide. Barium sulphide is used in the manufacture of luminous paint, and the nitrate and chlorate for producing the green light in pyrotechny. These various compounds of barium can, of course, be more easily prepared from the mineral witherite ($BaCO_3$); but, after suitable preliminary treatment, barytes can also be used for their production.

Many uses have been found for barytes in various other industries. For example, it is employed as a filling for rubber, oil-cloth, and linoleum; in the manufacture of wall-papers, and of commercial asbestos; as a pottery glaze; and as a substitute for lead in certain types of glass. Again, it is sometimes used to give opacity and weight to white papers, and to give lustre to glazed calicoes, and other fabrics.

Inferior grades of barytes, formerly regarded as of no commercial value, are now much utilised in the manufacture of a substance called lithopone, which in recent years has become

a product of considerable importance. This material is essentially a chemically prepared mixture of zinc sulphide and barium sulphate, but in addition it usually contains a small proportion of oxide of zinc. The process of manufacture consists in (1) the reduction of the crude barytes to barium sulphide, (2) the preparation of the precipitating zinc solutions, (3) the precipitation of the mixture of zinc sulphide and barium sulphate by the interaction of the products obtained in the first and second stages of the process, and (4) the after-treatment of the precipitate.

Barium sulphide is obtained from barytes by calcining the mineral with about one-fourth its weight of coal. The barytes and coal are ground together in a mill, and then introduced into a suitable furnace, where they are calcined at a white heat. During the process the mixture is kept in constant movement, and the ignition is continued until the reduction is as complete as possible. If the calcined mass be now treated with water, all the sulphide formed will come off in solution.

The preparation of the zinc solutions is a much more difficult and complex matter. For economical reasons only low-grade zinc ores, or the zinc-bearing by-products of certain metallurgical processes, are used as a source of the metal; and hence the manipulation of these, and the subsequent purification of the solutions obtained from them, call for the application of exceptional methods. In most cases the methods employed are highly technical, and their details are usually guarded as trade secrets. The treatment varies with individual manufacturers, and also, of course, according to the nature of the raw material employed.

The precipitation of lithopone takes place when the zinc and barium sulphide solutions are brought together. According to a common method for its preparation, the latter solution is divided into two parts, and to one of these is added a solution of zinc chloride. Zinc sulphide is immediately formed, but before it is allowed to settle, an estimated quantity of zinc sulphate, together with the remainder of the barium solution, is introduced into the mixture. As a result, a further reaction takes place, and a composite precipitate of zinc sulphide and barium sulphate separates out. The reaction may be represented by the following equation:—

$$ZnCl_2 + ZnSO_4 + 2BaS = 2ZnS + BaSO_4 + BaCl_2.$$

Other methods for the preparation of the material, involving somewhat different reactions, are also commercially employed.

The after-treatment of the precipitate consists in drying and igniting the material, and then grinding it to the necessary degree of fineness. When ground it is packed into barrels ready for the market.

Lithopone is largely used as a white paint, and also as a filling in the manufacture of rubber, paper, oil-cloth, linoleum,

asbestos, etc. As a paint it has the advantage of cheapness and it is of a pure white colour ; it likewise possesses a high covering power, and gives a beautiful smooth surface.

Economical conditions are naturally most appropriate for the establishment of a lithopone industry, where otherwise unmarketable, low-grade zinc-ores, and barytes occur in conjunction. As already stated, both such deposits are found together at Silvermines, Co. Tipperary. An enormous quantity of inferior zinc-ore (hemimorphite, and impure smithsonite) is still available in the so-called " gossan bed " of the dolomitic limestone of this locality. Barytes of low grade occurs also in the same formation, though apparently in more limited quantities ; but this could be supplemented, if necessary, from the better class material found in the fissure veins traversing the Silurian, and Old Red Sandstone rocks in the vicinity. Transport facilities are likewise not unfavourable. The locality is situated about four miles from Shallee Railway Station, and coal could be brought in by the Shannon waterway to Limerick or to Killaloe. Hence, a happy combination of circumstances would seem to mark out the locality as a favourable site for the establishment of lithopone works ; but whether the available raw materials are really suitable for the manufacture of the material is, of course, a matter for expert investigation.

INDEX.

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